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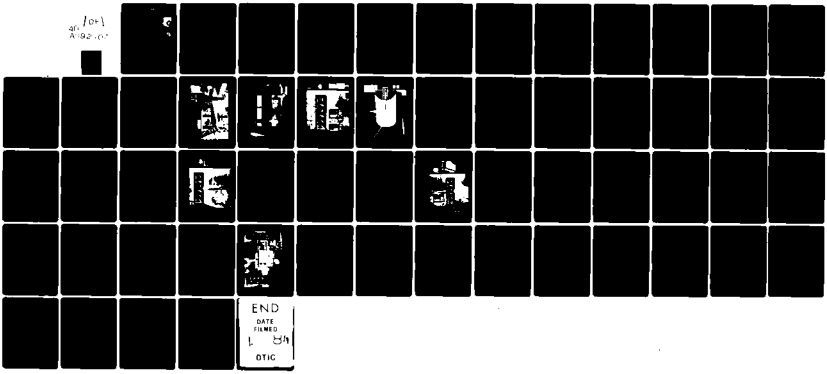

AFWAL-TR-80-2058 LEVEL II

EFFECTS OF ANTI-STATIC ADDITIVES ON AIRCRAFT CAPACITANCE FUEL GAGING SYSTEMS

AD A092907

Simmonds Precision Instrument Systems Division
Simmonds Precision Products
Panton Road
Vergennes, Vermont 05491

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FINAL REPORT May 1979 - November 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effects of increasing the electrical conductivity of JP-4 and Jet A jet fuels on aircraft capacitance fuel gauging systems were determined. Fuel tank capacitance probes from the KC-135, A-7, F-15, and F-16 aircraft were tested in JP-4 and Jet A fuels having electrical conductivities ranging from less than 20 pS/m to 5,000 pS/m. Additives ASA-3 (Shell Chemical Company) and Stadis 450 (E.I. Du Pont de Nemours and Company) were used to increase the conductivity of the fuel. The fuel tank capacitance gauging system parameters of accuracy, sensitivity, speed of response, and High Z null voltage were measured. The F-15

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and the F-16 systems were unaffected by fuel conductivities up to 5,000 pS/m. The A-7 and KC-135 systems indicated negligible effects at fuel conductivities up to 500 pS/m, and increasing system degradation at higher conductivity levels.

FOREWORD

This final report was submitted by the Simmonds Precision Instrument Systems Division, Simmonds Precision Products, Inc., of Vergennes, Vermont. The work was conducted under Contract F33657-79-C-0378. The contract was directed by the Information Engineering Division of the Deputy for Engineering, Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Mr. James M. Planet was the government project engineer.

Funding and technical guidance were provided by the Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, under Project 3048, "Fuels, Lubrication and Fire Protection", Task 304805, "Aero Propulsion Fuels", Program Element 62203F. The Aero Propulsion Laboratory project engineer was Mr. Charles R. Martel.

Minor changes have been made to the text and tables to accommodate the use of first order or second order, least squares curve fits for some of the experimental data.

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SECTION I

INTRODUCTION

This study was undertaken to determine the effect of varying fuel conductivity levels on aircraft capacitance fuel gauging systems. Fuel conductivity levels were raised using anti-static additives. These additives are used to preclude the build-up of dangerous static charges during fueling operations.

Four aircraft systems were tested. The KC-135 and the A-7 systems represented the older 400 Hz AC design, and the F-15 and F-16 systems represented the newer high frequency DC design.

SECTION II

OBJECTIVE

The objective of this test program was to determine the effect of varying jet fuel electrical conductivity on the parameters of accuracy, sensitivity, speed of response, and High Z null voltage for four aircraft capacitance fuel gauging systems. A decision could then be made concerning the highest fuel conductivity level that could be specified without impairing fuel gauging system performance.

An additional objective was to determine if any significant difference in gauging system performance existed with different fuel and additive combinations. Jet A and JP-4 fuels were used in conjunction with fuel conductivity additives ASA-3 and Stadis 450, produced by Shell Chemical Company and E. I. du Pont de Nemours Co., Inc., respectively.

SECTION III

TEST PLAN

The following basic test plan was followed:

1. SYSTEMS TESTED

Four military capacitance fuel gauging systems were tested; F-15, F-16, A-7, and KC-135.

2. FUELS AND ADDITIVES

Each of the systems was tested with two fuels, JP-4 and Jet A, and two anti-static additives, ASA-3 and Stadis 450. Fuel conductivity levels were raised in steps to a maximum level in excess of 3500 pS/m (picosiemen/meter or 10^{-12} ohm^{-1} $meter^{-1}$).

3. CONDUCTIVITY MEASUREMENTS

Fuel conductivity measurements were made with an Emcee Electronics, Inc. conductivity meter, model 1151A, to the requirements of ASTM D2624. The meter was modified by the manufacturer to extend the range to 5000 pS/m.

4. TEST PROCEDURES

The following procedure was used to obtain the required data. The data were obtained in two sets. The F-15 and KC-135 systems were tested together for the first set and the A-7 and F-16 systems were tested together for the second set.

a. Probes and compensator were mounted in the tank.

b. The tank was filled with fresh, undoped fuel.

c. Fuel conductivity was recorded. The fresh fuel conductivity was 20 pS/m or less for all runs.

d. The fuel was allowed to stabilize for 24 hours initially, but this was later modified to approximately 4 hours.

e. Fuel conductivity was again checked.

f. Indicator readings were recorded at approximately 10%, 45%, and 95% of full level. The exact levels were highly repeatable because they were obtained by draining the fuel off at various levels through drain holes located in the tank wall.

The indicator readings at each level were recorded, along with the speed of response at the maximum level, system sensitivity, and high Z null voltage. High Z and low Z voltages are designated on each system schematic (Figures 1, 14, and 15). Low Z is the probe excitation voltage and high Z is the probe return signal voltage. The high Z is balanced (nulled) by the signal conditioner to provide an indicator reading.

g. The anti-static additive was added to the fuel using an eyedropper and the fuel-additive blend was then thoroughly mixed.

h. Steps d. through g. were repeated, until the maximum conductivity level was reached.

SECTION IV

RESULTS

1. KC-135 SYSTEM

a. Test Set-Up

A schematic describing the test set-up for this system is shown in Figure 1. Photographs of the test equipment are shown in Figures 2 through 5.

The fuel quantity systems under study normally have several probes in a given tank to compensate for aircraft attitude changes.

In this test,only one probe was required to show effects of fuel conductivity provided care was taken to adjust the system for any difference in empty probe capacitance. This was accomplished by inserting a precision Gertsch ratio transformer in the Lo-Z line to the probe. The Gertsch ratio transformer adjusted the Lo-Z voltage to the probe (up or down) such that the empty probe provided a zero fuel quantity reading on the indicator. This ratio transformer then became a permanent part of the test set-up and the ratio remained constant for all readings. This also allowed a convenient and accurate method of determining system sensitivity by offsetting the ratio transformer in small increments until the indicator responded.

The change in transformer ratio was converted to lbs. sensitivity by the formula:

$$\text{lbs. sensitivity} = \frac{\Delta\,\text{ratio}}{0.1} \times \left[\begin{array}{l}\text{lbs. change in reading caused}\\ \text{by 0.1 ratio change}\end{array}\right]$$

b. Data obtained

The data obtained on the KC-135 system are tabulated in the Appendix, Tables A-1 through A-4. These data are also presented in graphical form in Figures 6 through 12. These figures are discussed below.

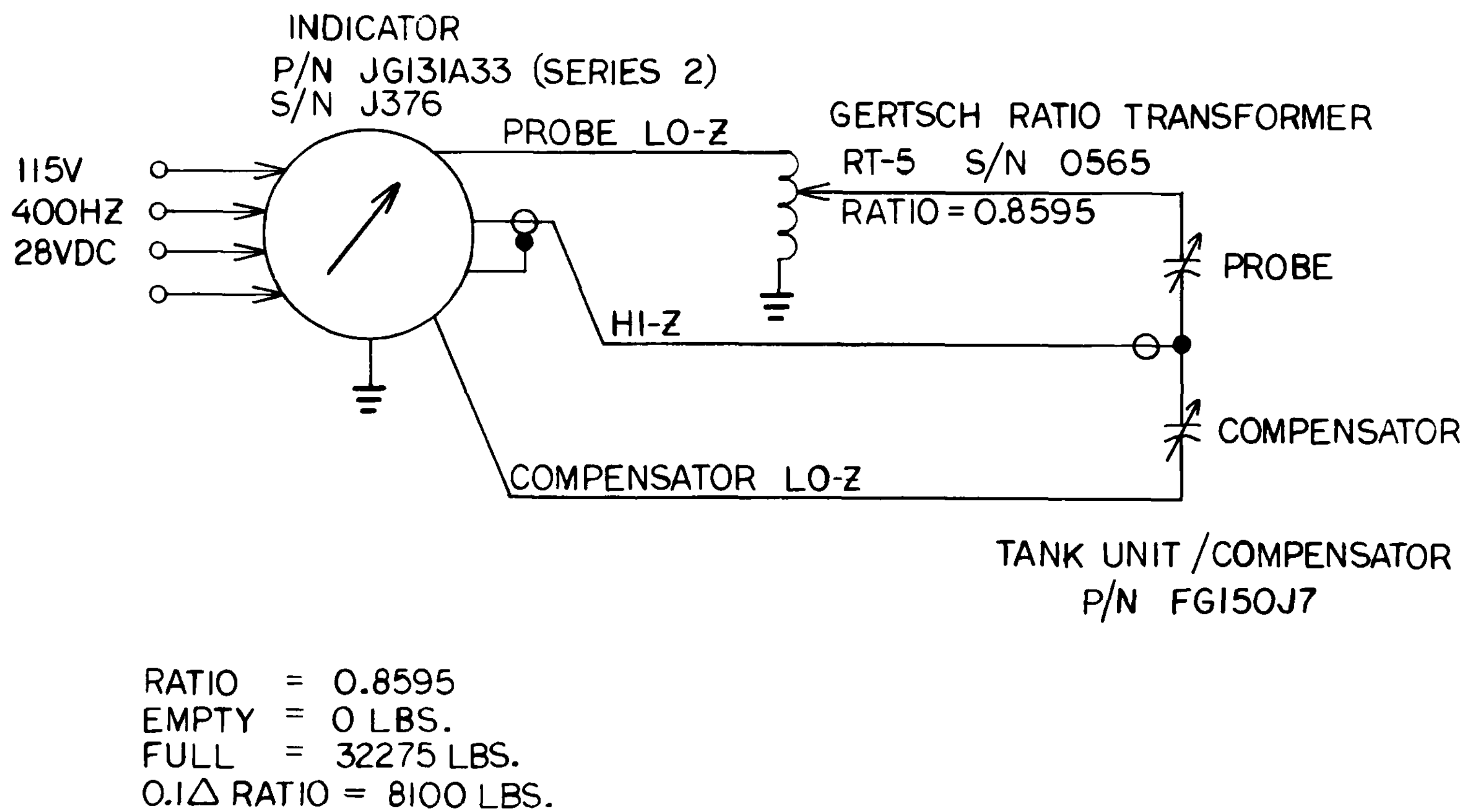

Figure 1. KC-135 Test Set-Up

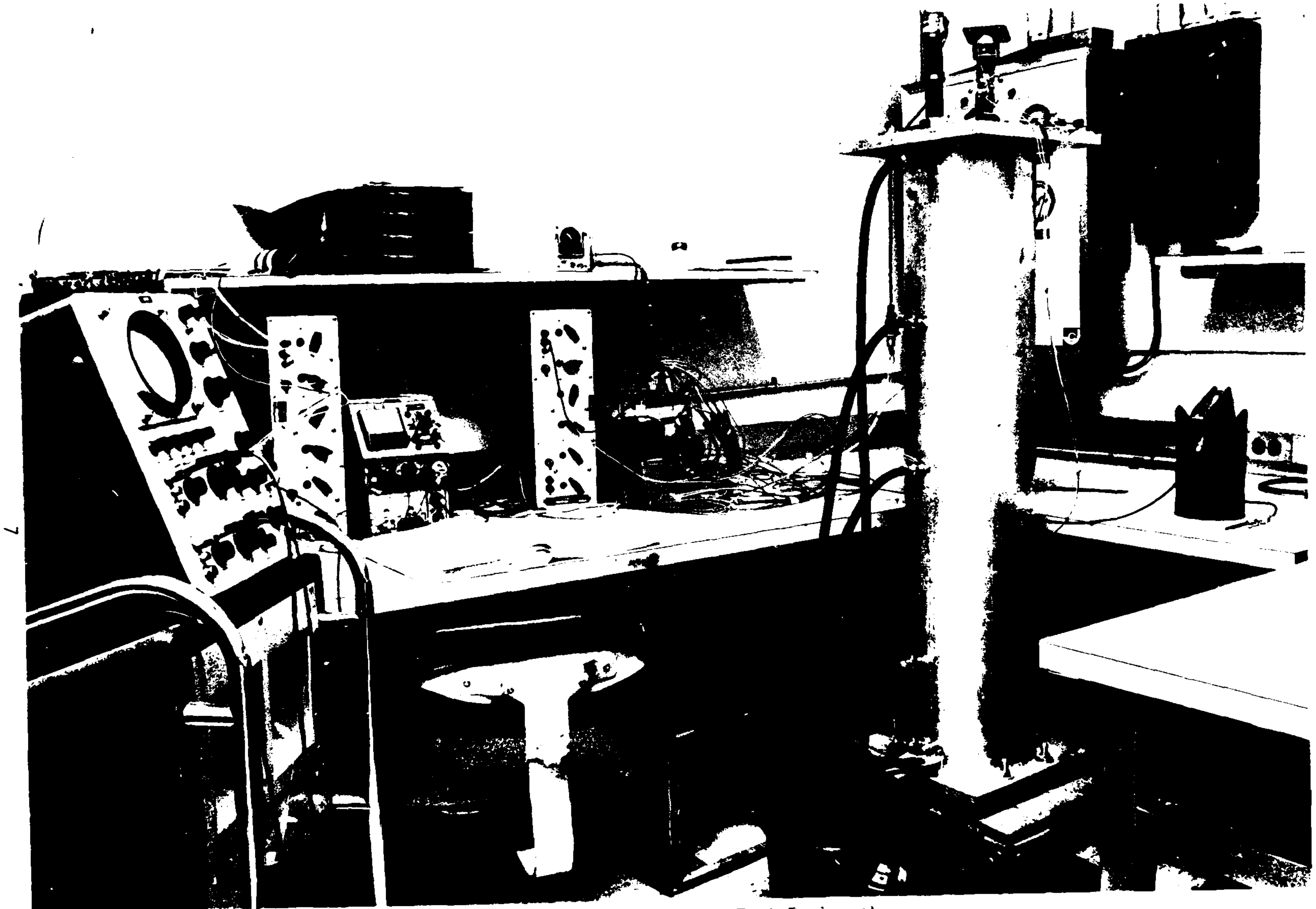

Figure 2. Anti-Static Additive Study Test Equipment

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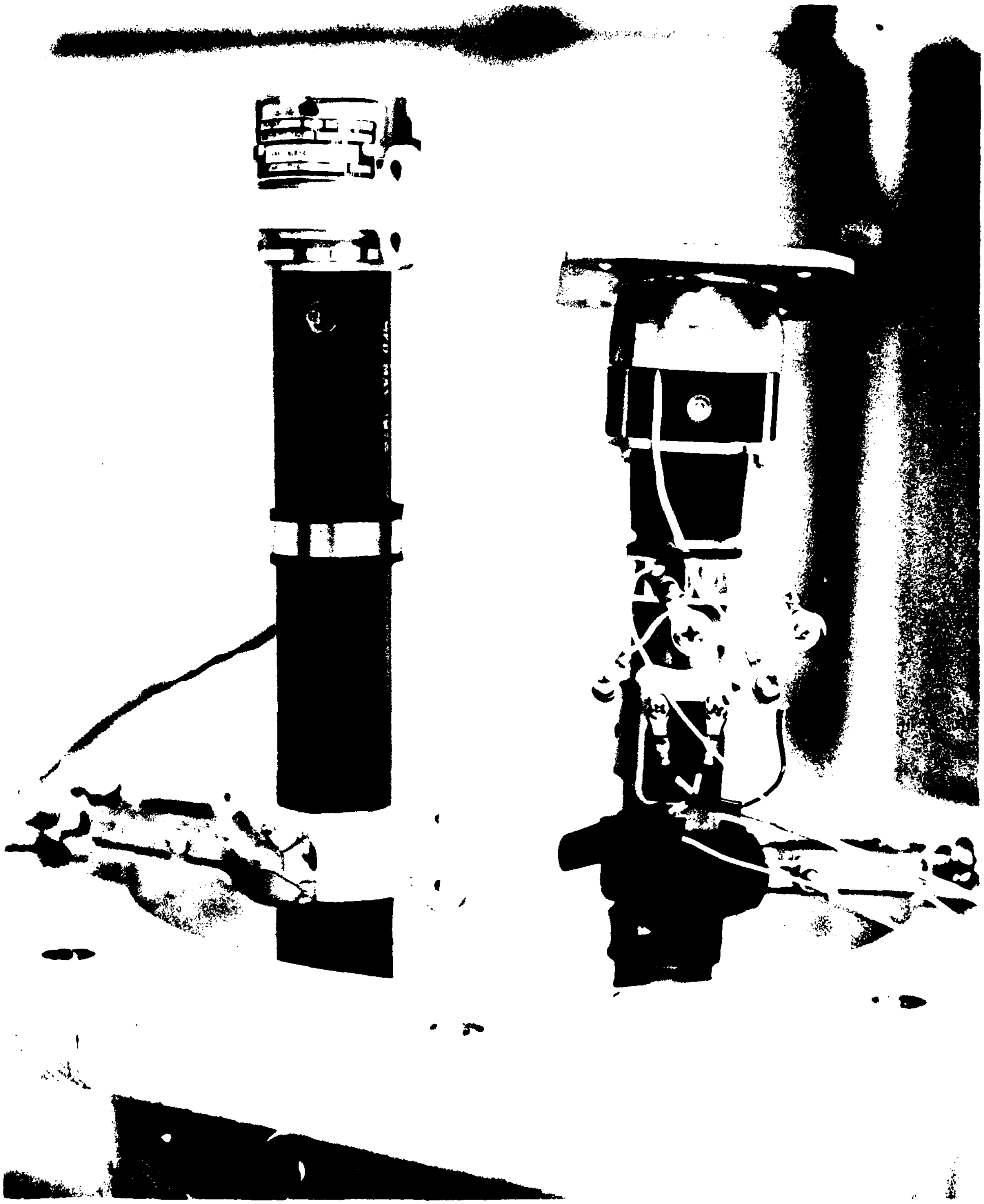

Figure 3. KC-135 (Left) and F-15 (Right) Tank Units

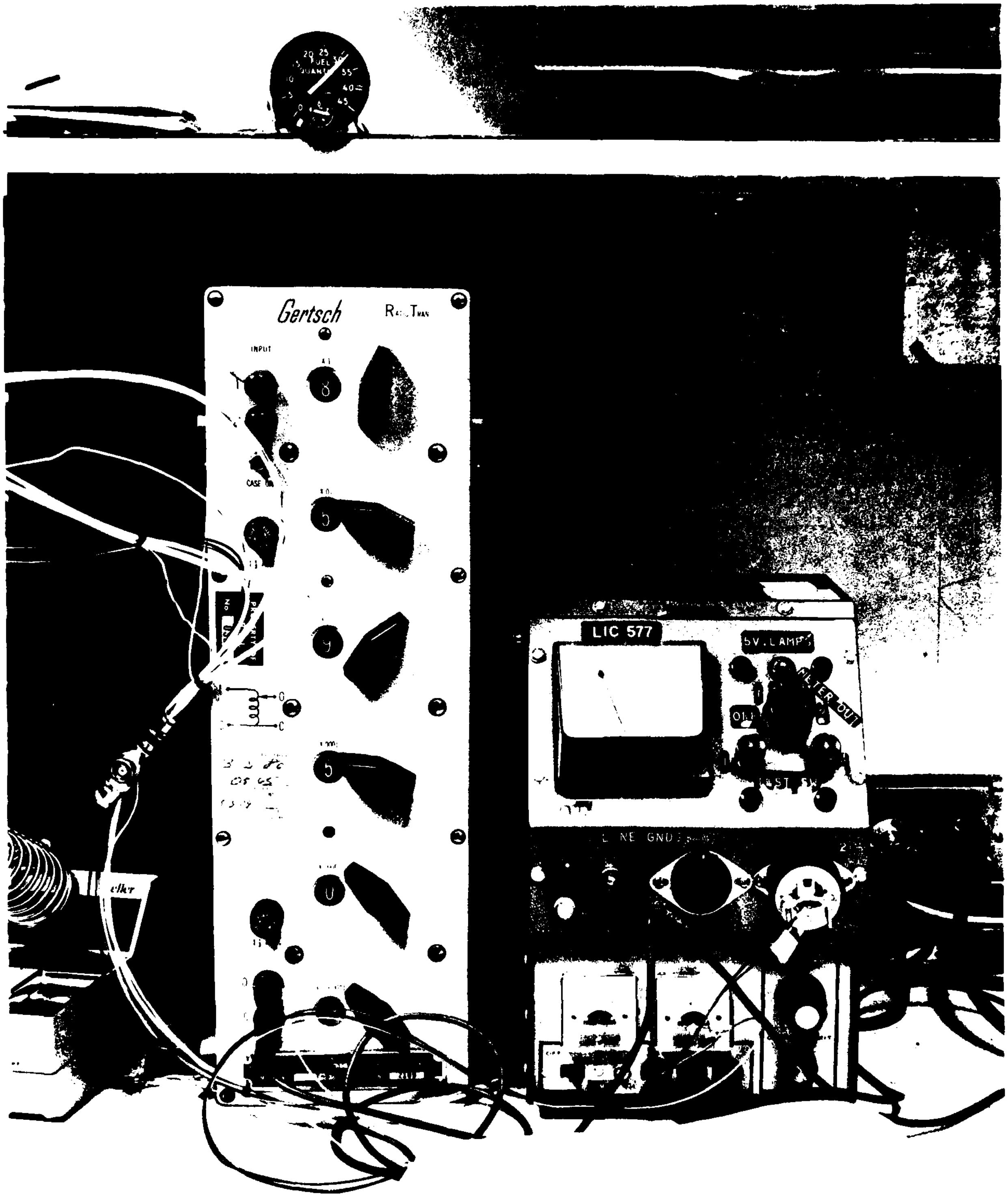

FIGURE 4 KC-135 Indicator, Gertsch Ratio Transformer, and Power Supply

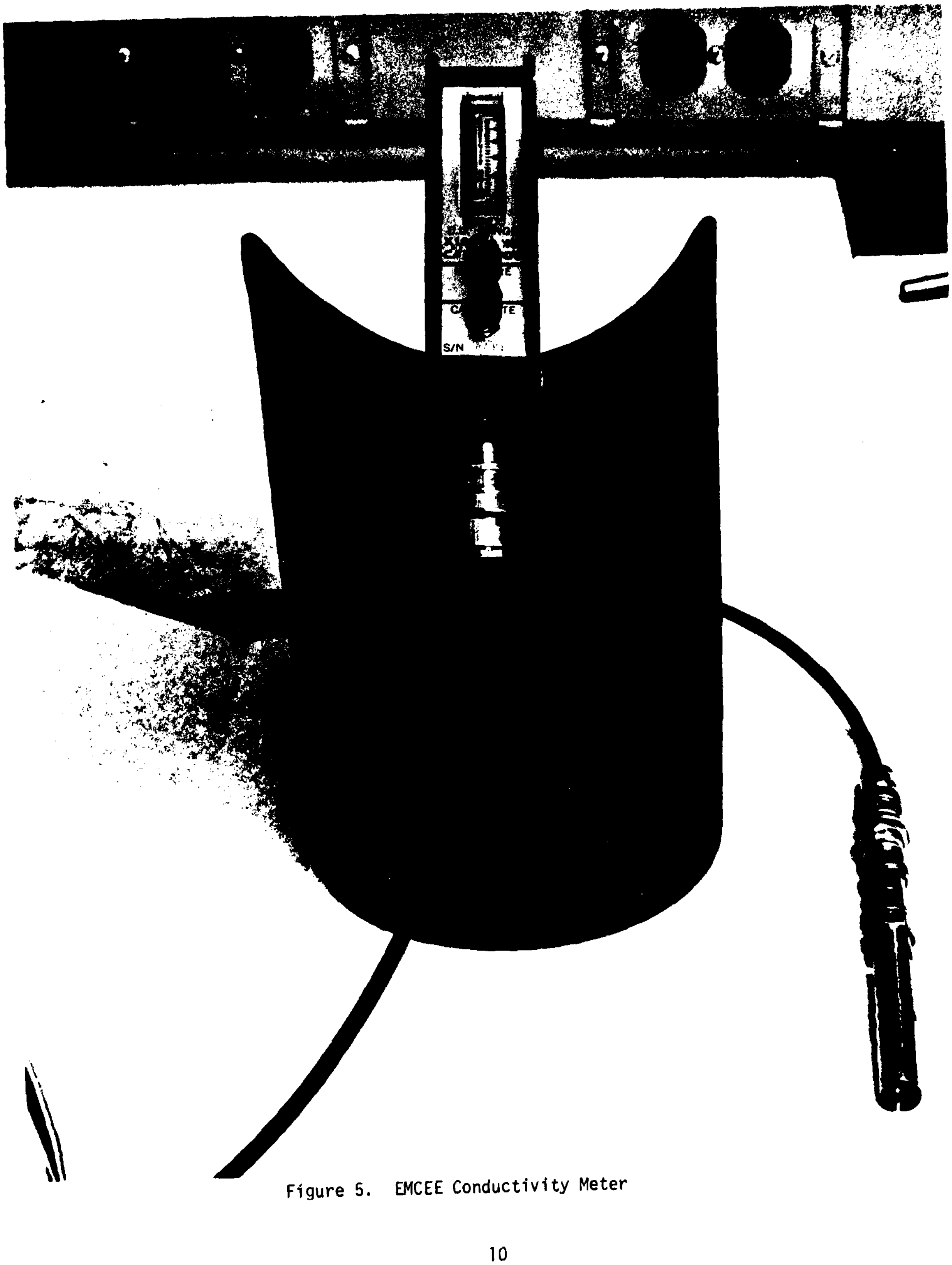

Figure 5. EMCEE Conductivity Meter

(1) Indicator Reading

Figure 6 is a plot of the increase in indicator reading vs. fuel conductivity at the 9 3/8" fuel level. Second order, least squares regression curves have been fitted to the four data sets. The average increases at different fuel conductivities are given below:

Conductivity (pS/m)	Average % Increase
500	1.8
1000	3.4
2000	6.7
3000	10.2
4000	13.8

Considerable scatter in the data is evident in Figure 6.

Figure 7 presents the same information observed at the 24 1/4" fuel level. The scatter in the data at this fuel level was somewhat less, and the average indicator reading increases were as follows:

Conductivity (pS/m)	Average % Increase
500	1.3
1000	2.6
2000	4.7
3000	6.3
4000	7.3

Figure 8 shows the indicator data taken at the 35 1/4" level. The scatter is again reduced, with the following average results:

Conductivity (pS/m)	Average % Increase
500	1.1
1000	2.0
2000	3.5
3000	4.4
4000	4.6

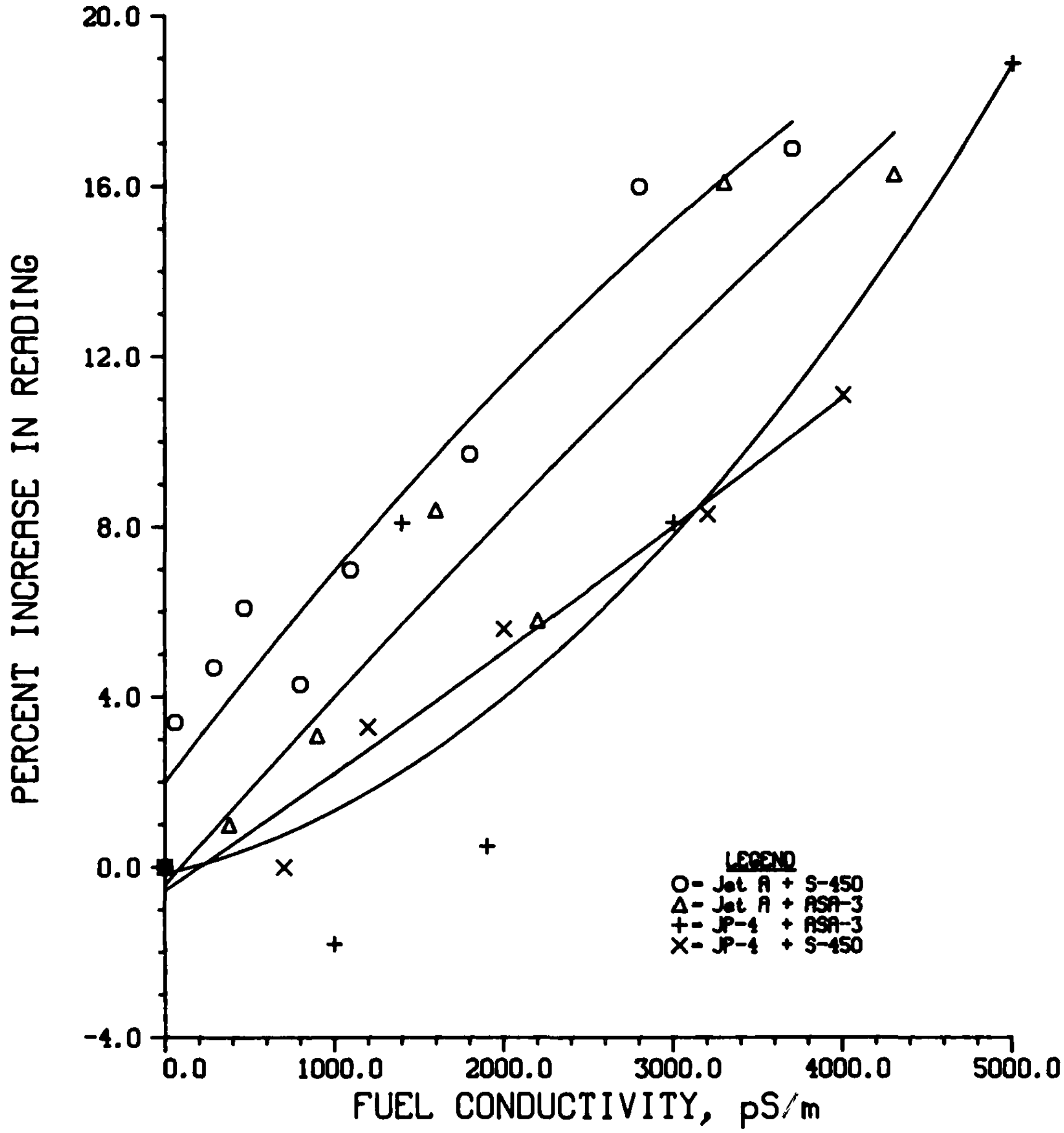

Figure 6. Conductivity Effect on KC-135
Level 9³/₈

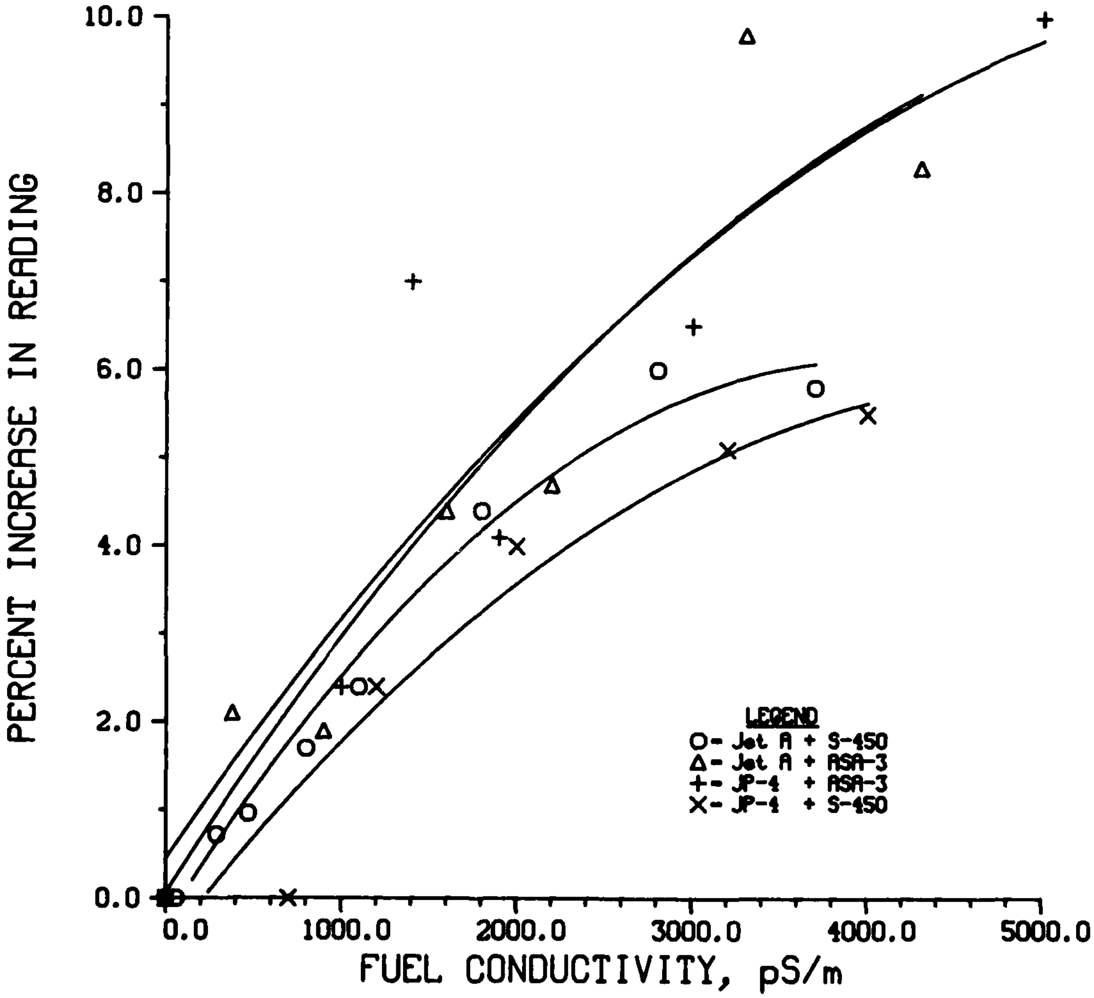

Figure 7. Conductivity Effect on KC-135 Level 24¹/₄

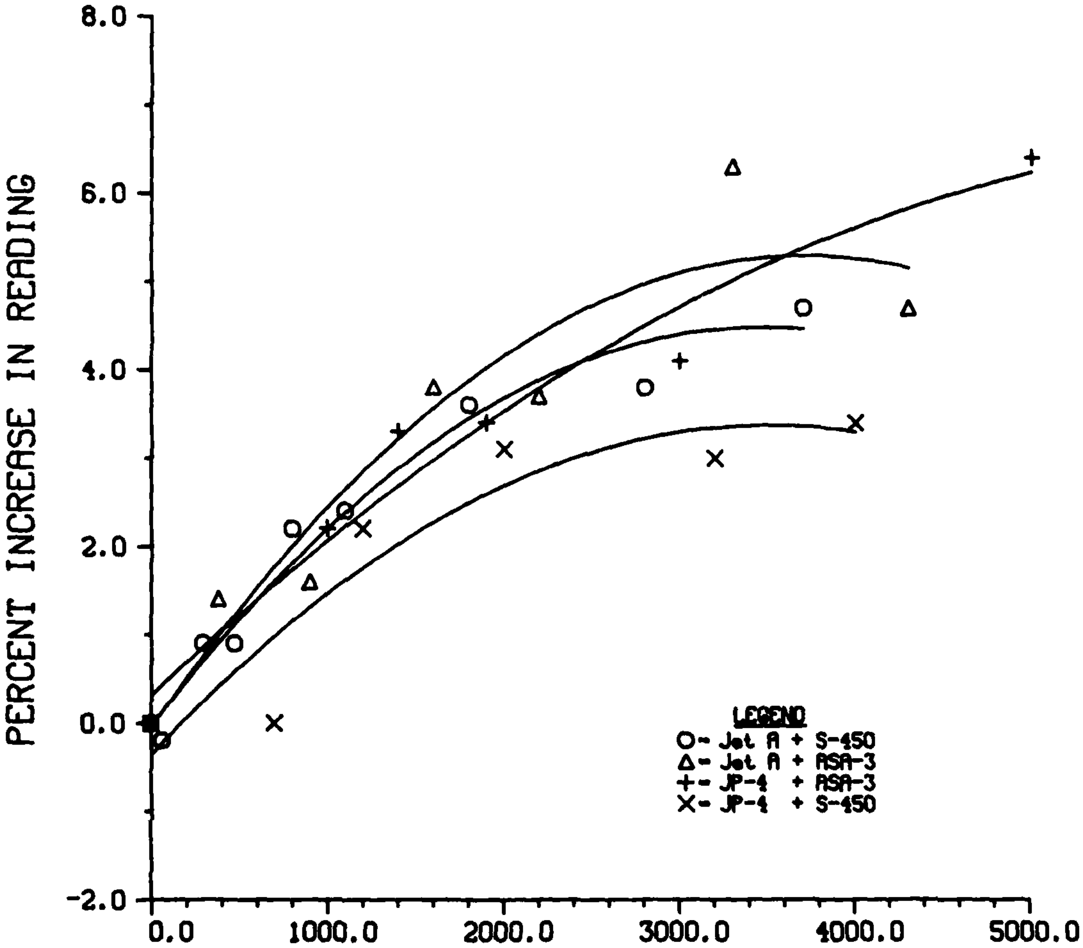

Figure 8. Conductivity Effect on KC-135 Level 35¹/₄

Figure 9 shows the same results at the maximum fuel level of 47 3/8", with the following reading increases:

Conductivity (pS/m)	Average % Increase
500	0.8
1000	1.5
2000	2.5
3000	3.1
4000	3.1

On a percent error basis, the effects of increased fuel conductivity were much higher at the low fuel levels.

(2) Sensitivity

Figure 10 is a plot of sensitivity (as a change in ratiometer setting) vs fuel conductivity for the KC-135 system. An increase in the change of ratiometer setting required to cause indicator movement indicates a decrease in system sensitivity.

The data indicated that at 5000 pS/m, the system sensitivity had decreased by a factor of approximately 7. At 1000 pS/m, the sensitivity had decreased by approximately 50%. Using the equation given on page 5 relating the Δ ratio to lbs. sensitivity, the following changes in lbs. sensitivity are indicated.

Conductivity (pS/m)	Average Sensitivity Lbs.	% Of Full Scale
20	81	0.25
500	105	0.32
1000	122	0.38
2000	203	0.63
5000	567	1.76

(3) Speed of Response

The speed of response for the KC-135 system was measured at full scale by disconnecting the Lo-Z lead from the ratiometer, allowing the indicator reading to go to zero, and then re-connecting the lead and timing, with a stop-watch, how long it took the indicator to go to full scale. The results obtained are presented in Figure 11

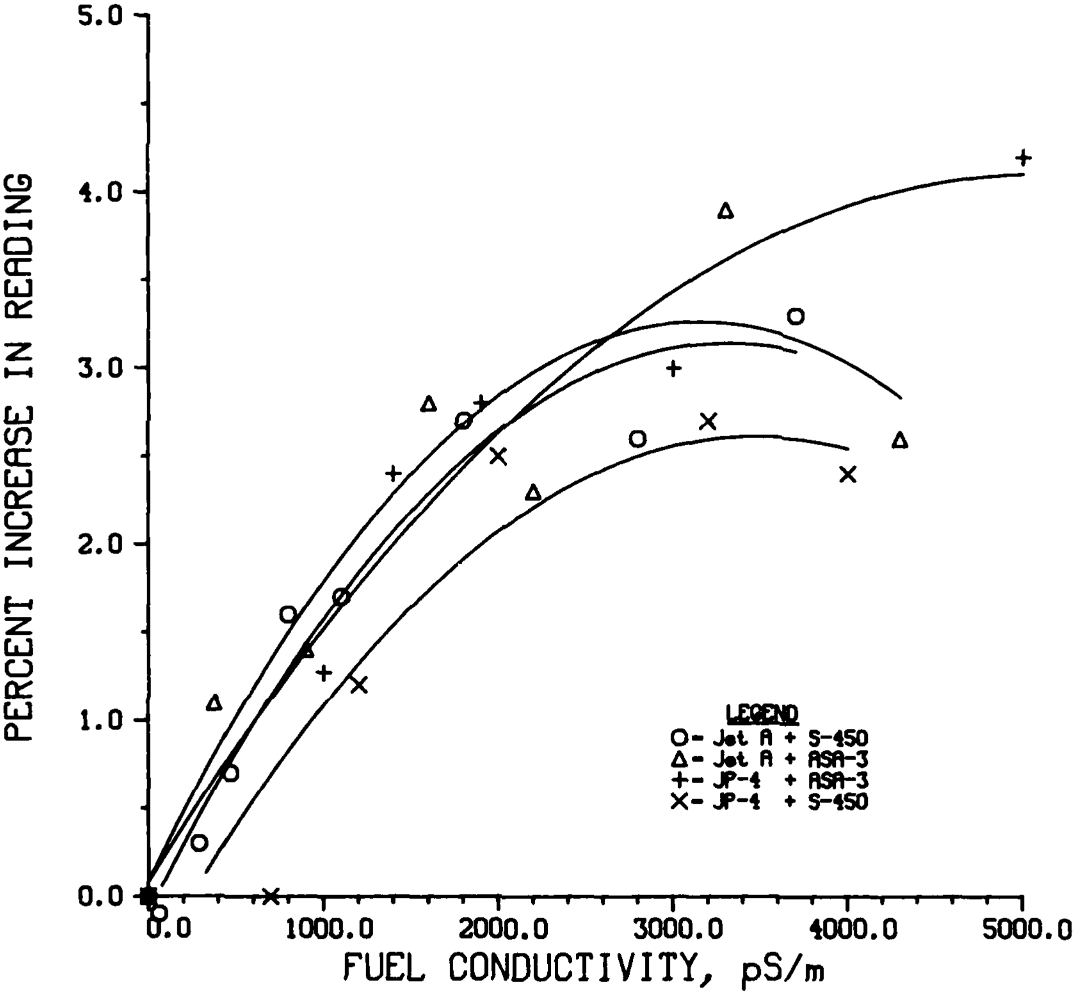

Figure 9. Conductivity Effect on KC-135 Level 47³/₈

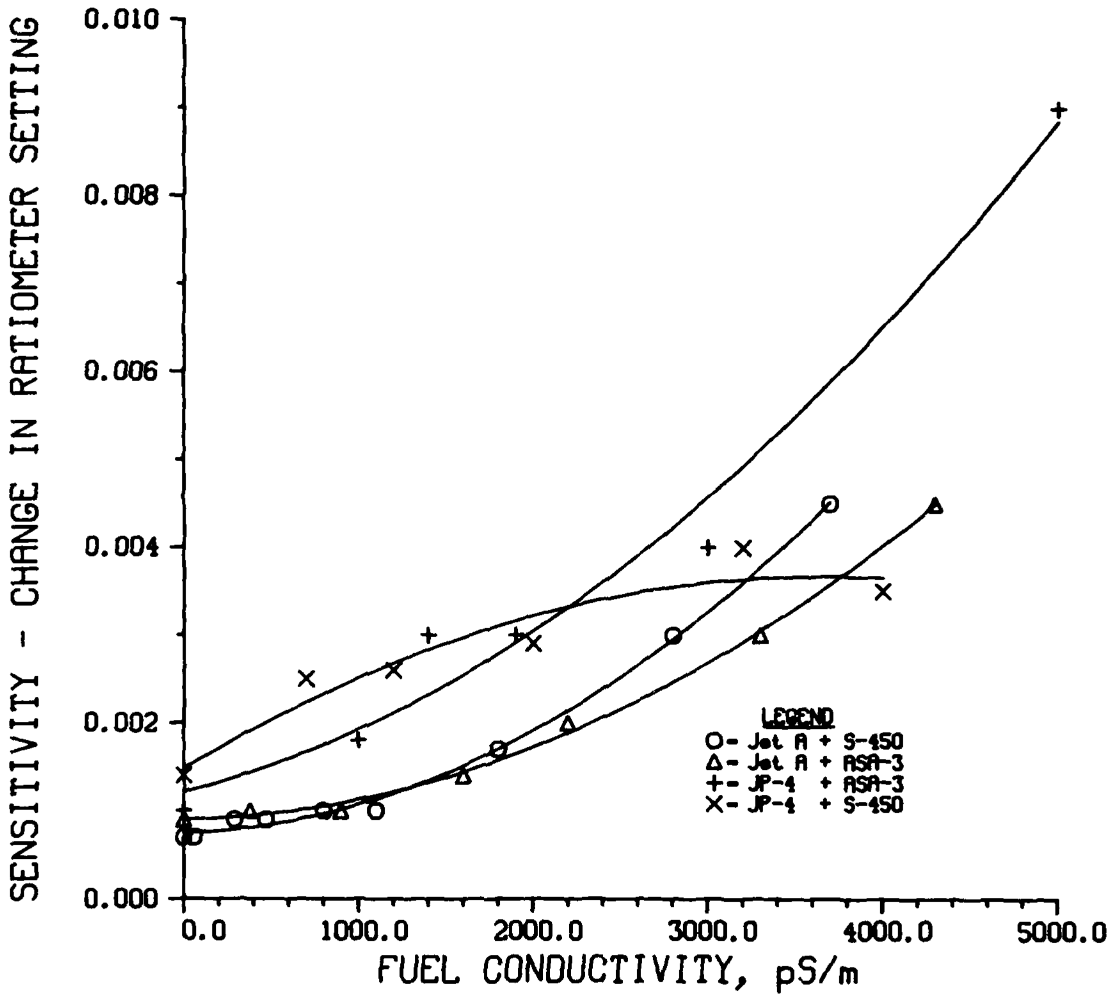

Figure 10. Sensitivity vs Fuel Conductivity
KC-135 System

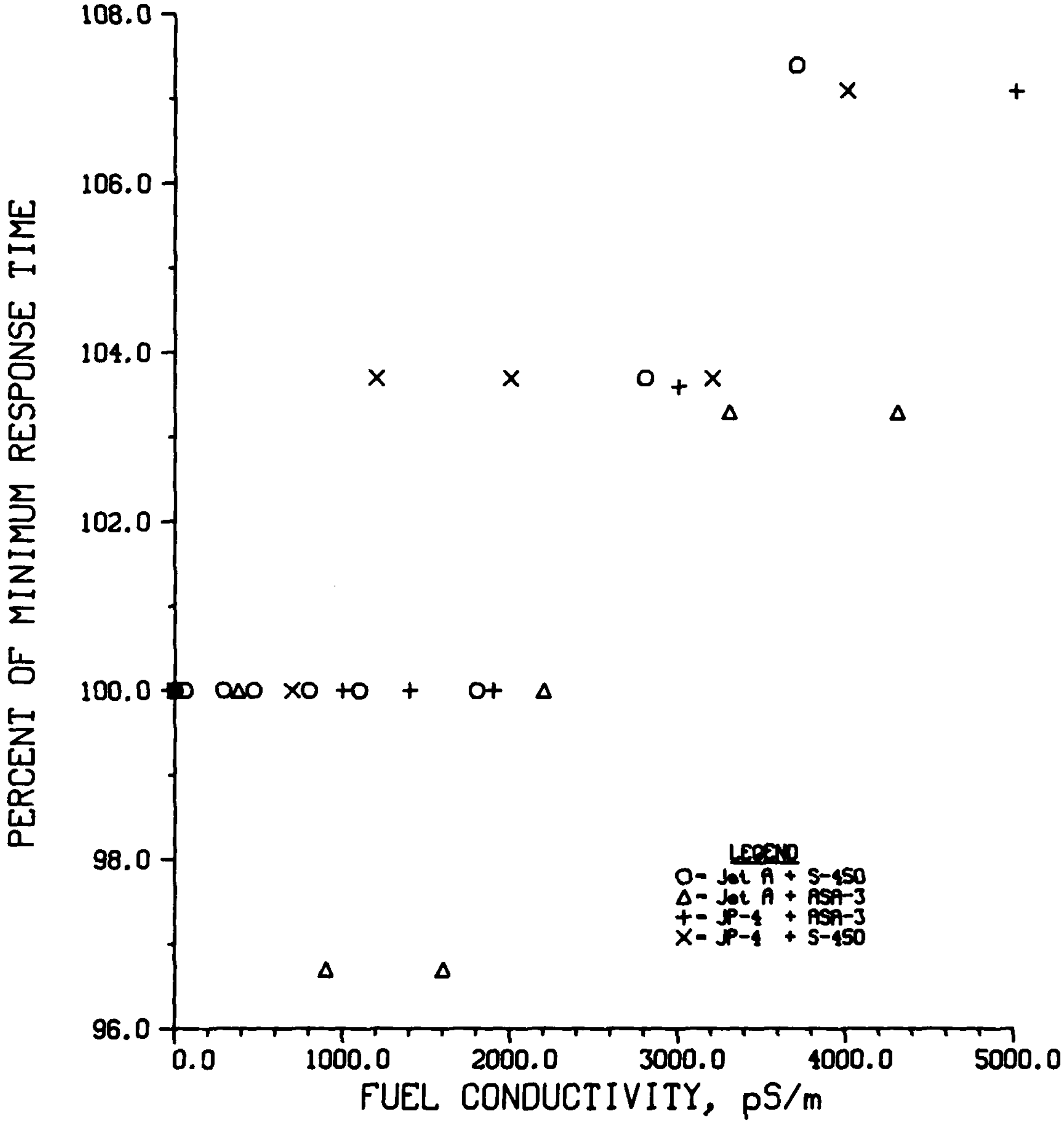

Figure 11. Percent of Minimum Response Time vs Conductivity KC-135 System

Essentially no change in response time was observed until a fuel conductivity of approximately 2000 pS/m was reached. Between 2000 and 5000 pS/m, increases in response time ranged between 2% to 8%, or 1 or 2 seconds out of 28 seconds.

(4) High Z Null Voltage

The high Z null voltage was measured as a peak-to-peak AC voltage using an oscilloscope. The data obtained are presented in Figure 12.

The data indicated a trend toward higher voltages at conductivities above 2000 pS/m, but the large amount of scatter in the data precluded any positive conclusion as to the amount of the increase. The scatter in the data was probably due to the fact that the servo slews into a null not only on drive voltage, but on momentum balanced by different friction loads at various gear train positions. This produced a random effect on high Z null voltage which was a measure of how close the servo came to a true null before stopping.

2. F-15 SYSTEM

a. Test Set-Up

The test set-up for the F-15 system was similar to that for the KC-135, except no separate compensator unit was used. Photographs of the test equipment are shown in Figures 2, 3, 5, and 13. A schematic for this set-up is shown in Figure 14.

The High Z null voltage measurement and the system response time were not measured since a preliminary check indicated there would be no change with the conductivity levels experienced. The theoretical analysis (Section V) concurred with these findings.

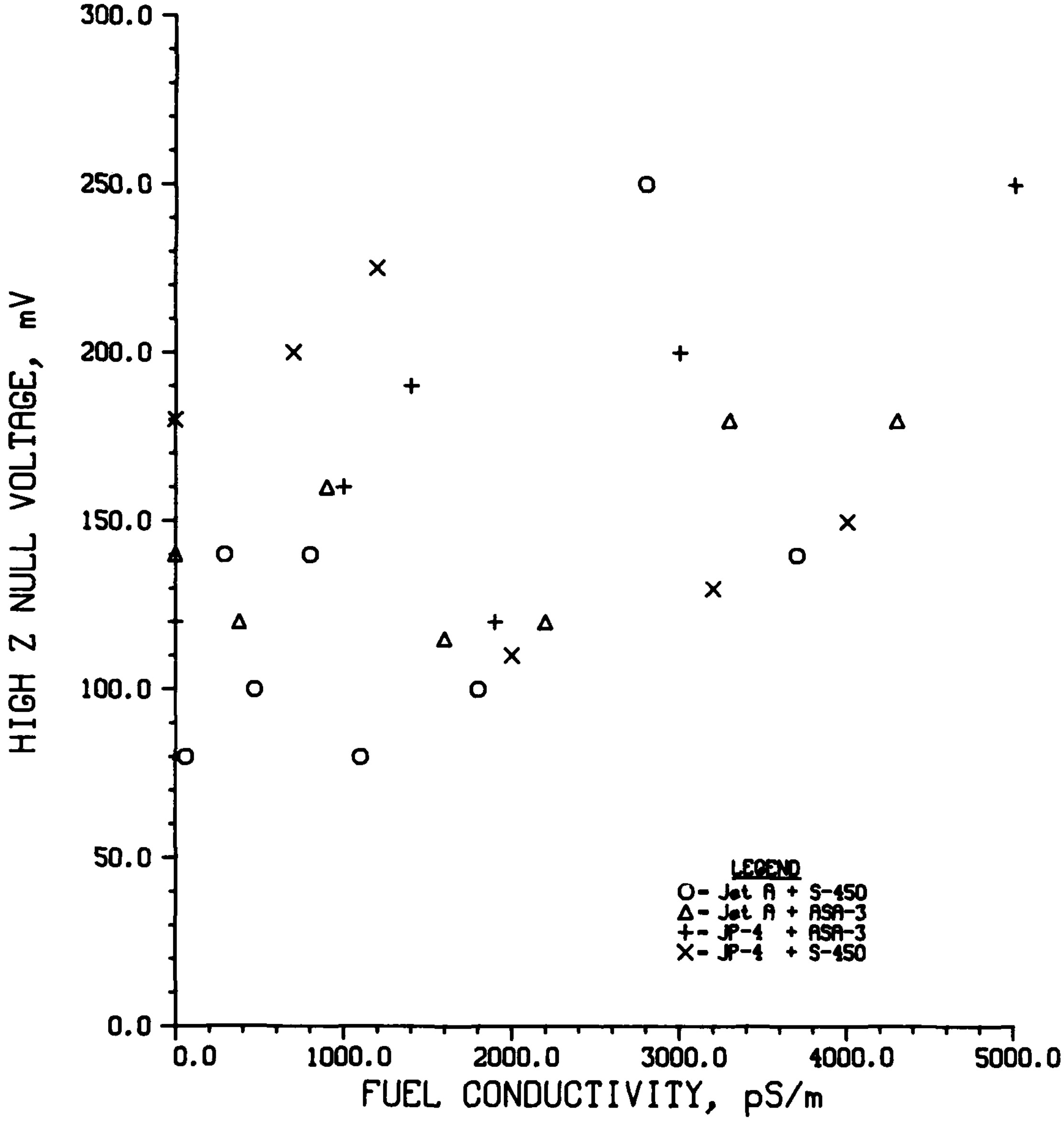

Figure 12. High Z Null Voltage vs Fuel Conductivity
KC-135 System

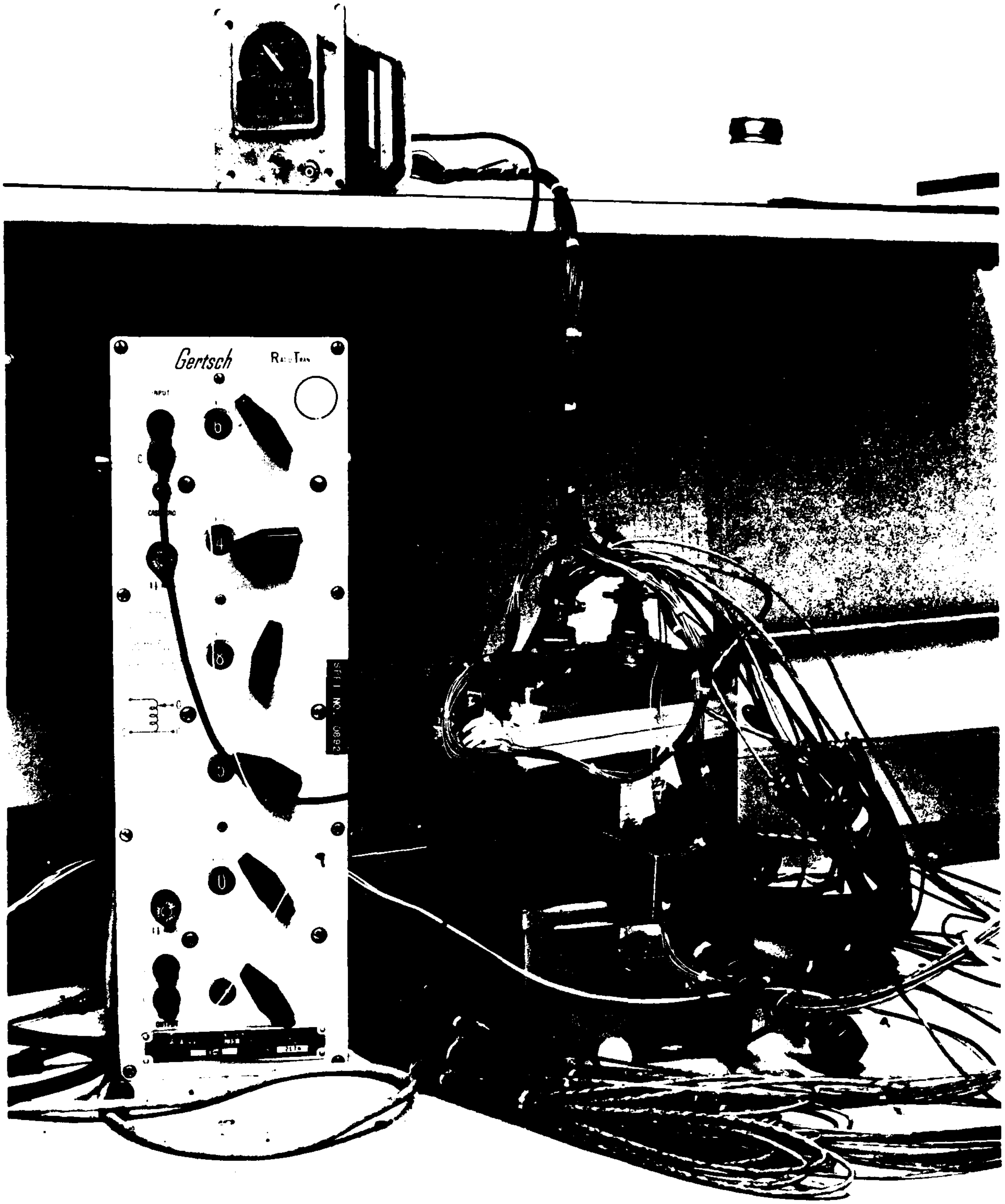

Figure 13. F-15 Indicator, Control Unit, and Gertsch Ratio Transformer

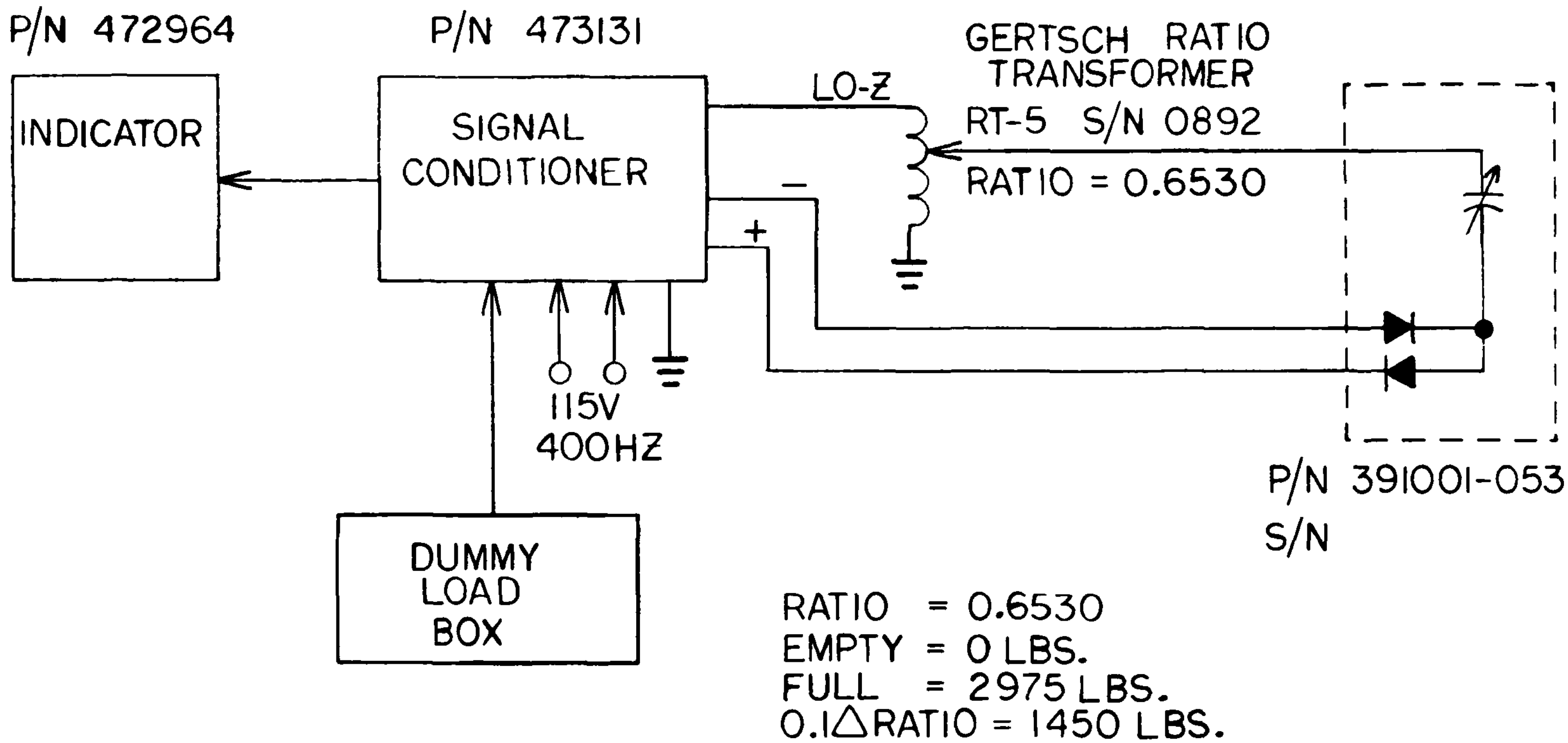

Figure 14. F-15 Set-Up

b. Data Obtained

The data obtained on the F-15 system are tabulated in the Appendix, Tables A-5 through A-8. Since there were virtually no changes observed with the increases in fuel conductivity, no graphs of these data were prepared.

(1) Full Scale Reading

A maximum reading of 2800 to 2950 lbs. was obtained with the test set-up. The normal system maximum for this channel is 4200 lbs. For the purposes of this test the value obtained was sufficient.

The Jet A fuel with both additives caused no significant effect on the readings even at conductivity levels of 5000 pS/m. The JP-4 with the ASA-3 additive indicated an increase of 25 lbs. in the full reading between 1900 pS/m and 4000 pS/m. Some of this increase may have been due to interpretation of the counter reading at the intermediate position. Since the sensitivity readings did not change for the entire range of conductivity, the 25 lb. change did not appear to be significant.

(2) Sensitivity

All of the data obtained indicated no change in system sensitivity for fuel conductivity levels up to 5000 pS/m. A sensitivity value of 0.0004 was obtained; this corresponds to a reading sensitivity of 5.80 lbs. using the equation given on page 5.

3. A-7 SYSTEM

a. Test Set-Up

A schematic describing the test set-up is shown in Figure 15. The set-up was similar to that used for the KC-135 system. The compensator in this system was a separate, wirewound device which was placed in the fuel tank along with the probe. The readout in this case was a 5-digit counter reading in increments of 100 lbs. A photograph of the test equipment is shown in Figure 16.

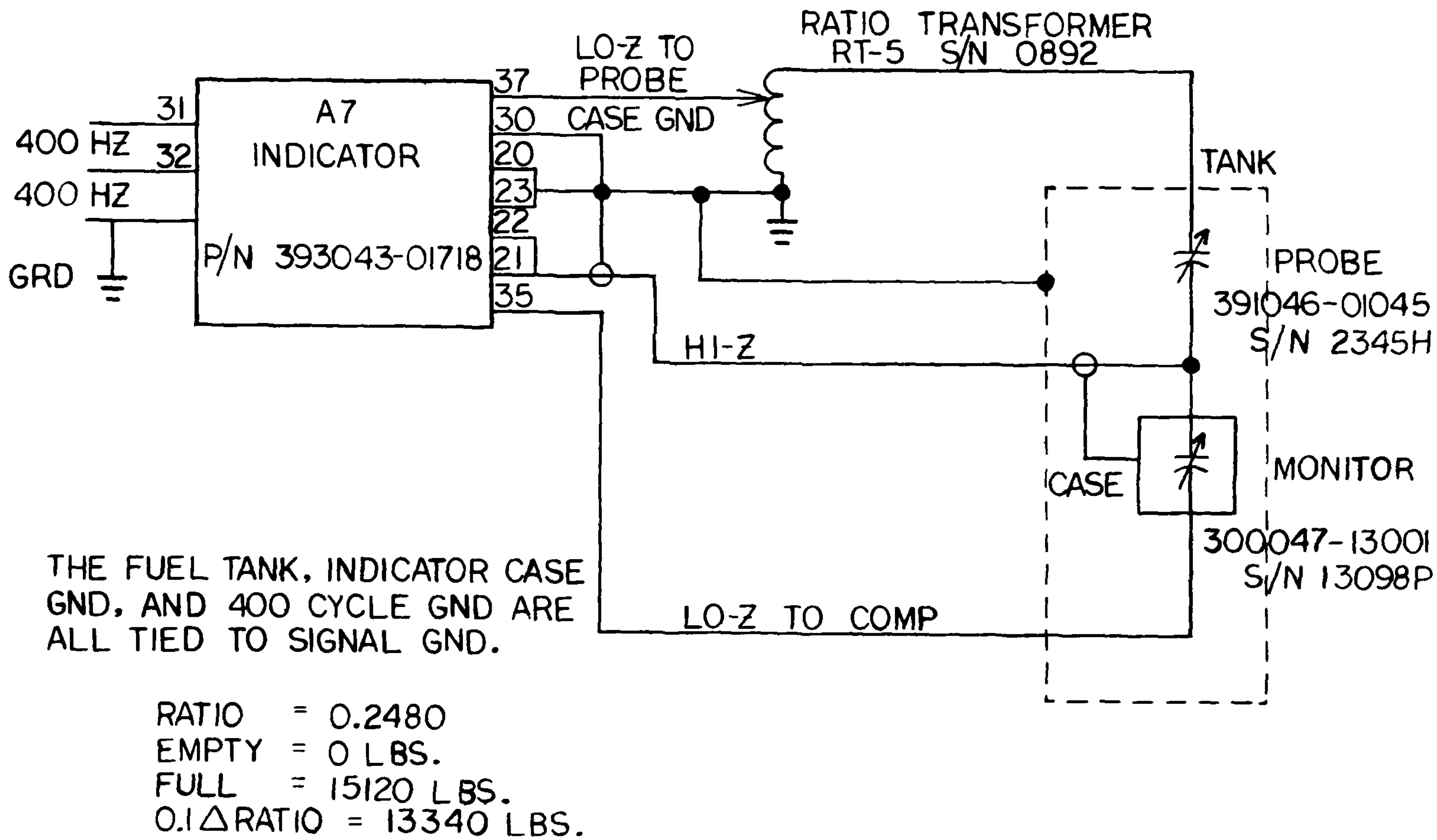

Figure 15. A-7 Test Set-Up

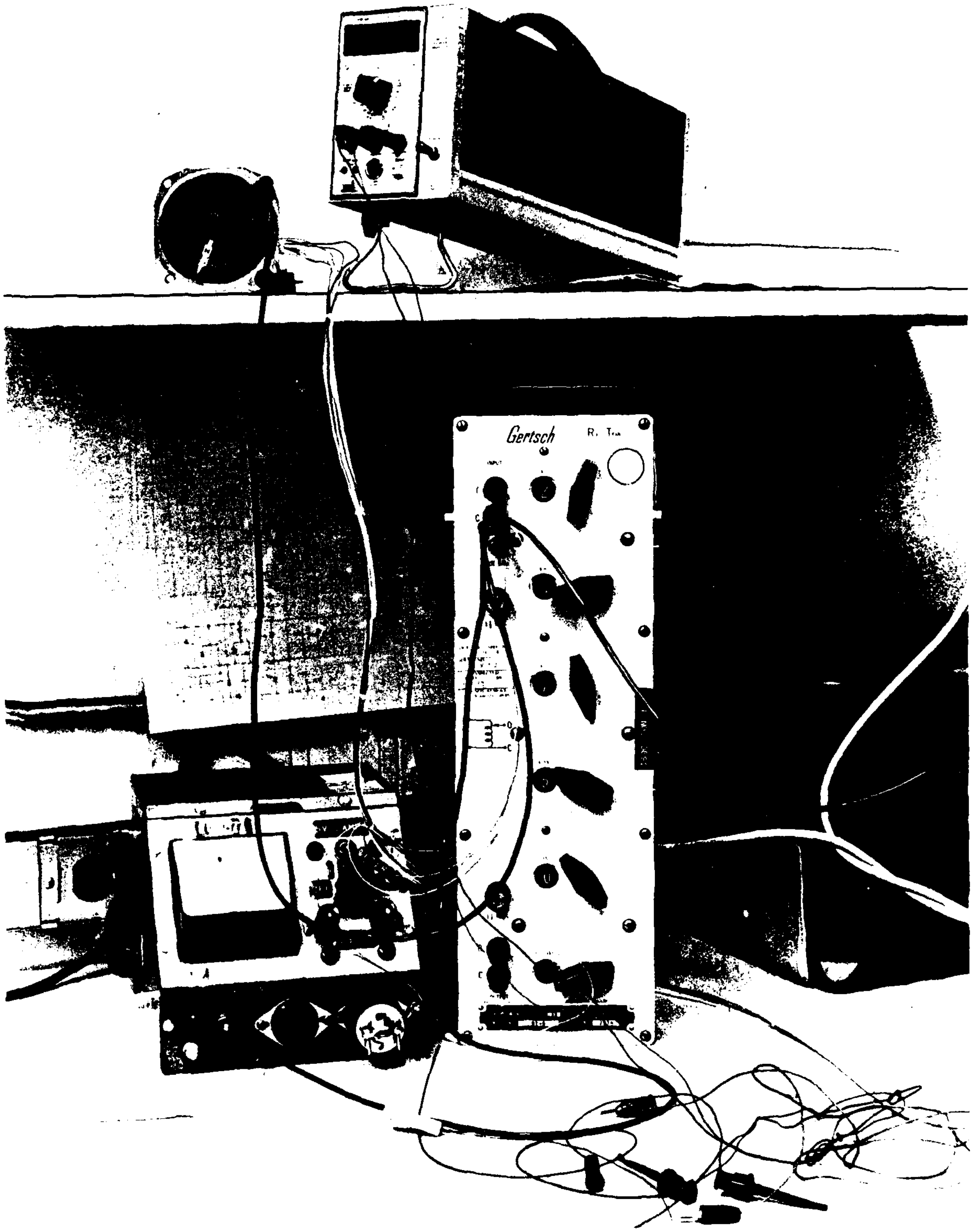

Figure 16. A-7 Indicator, Ratio Transformer, and Power Supply

b. Data Obtained

The data obtained on the A-7 system are tabulated in the Appendix, Tables A-9 through A-12. These data are also presented in graphical form in Figures 17 through 22. These figures are discussed below.

(1) Indicator Reading

Figure 17 is a plot of the percent increase in indicator reading at the 9 3/8" fuel level vs fuel conductivity. As with the KC-135 system, there was considerable scatter in the data, with the following average results obtained from curves drawn through the data:

Conductivity (pS/m)	Average % Increase
500	0.02
1000	-0.09
2000	0.06
3000	0.69
4000	1.86

These increases in indicator readings were considerably less than those observed with the KC-135 equipment.

Figure 18 presents the same information for the 24 1/4" fuel level, as follows:

Conductivity (pS/m)	Average % Increase
500	0.2
1000	0.5
2000	1.1
3000	1.8
4000	2.5

Figure 19 shows the increase in reading vs fuel conductivity at the maximum fuel level. The average results are as follows:

Conductivity (pS/m)	Average % Increase
500	0.03
1000	0.24
2000	0.8
3000	1.6
4000	2.5

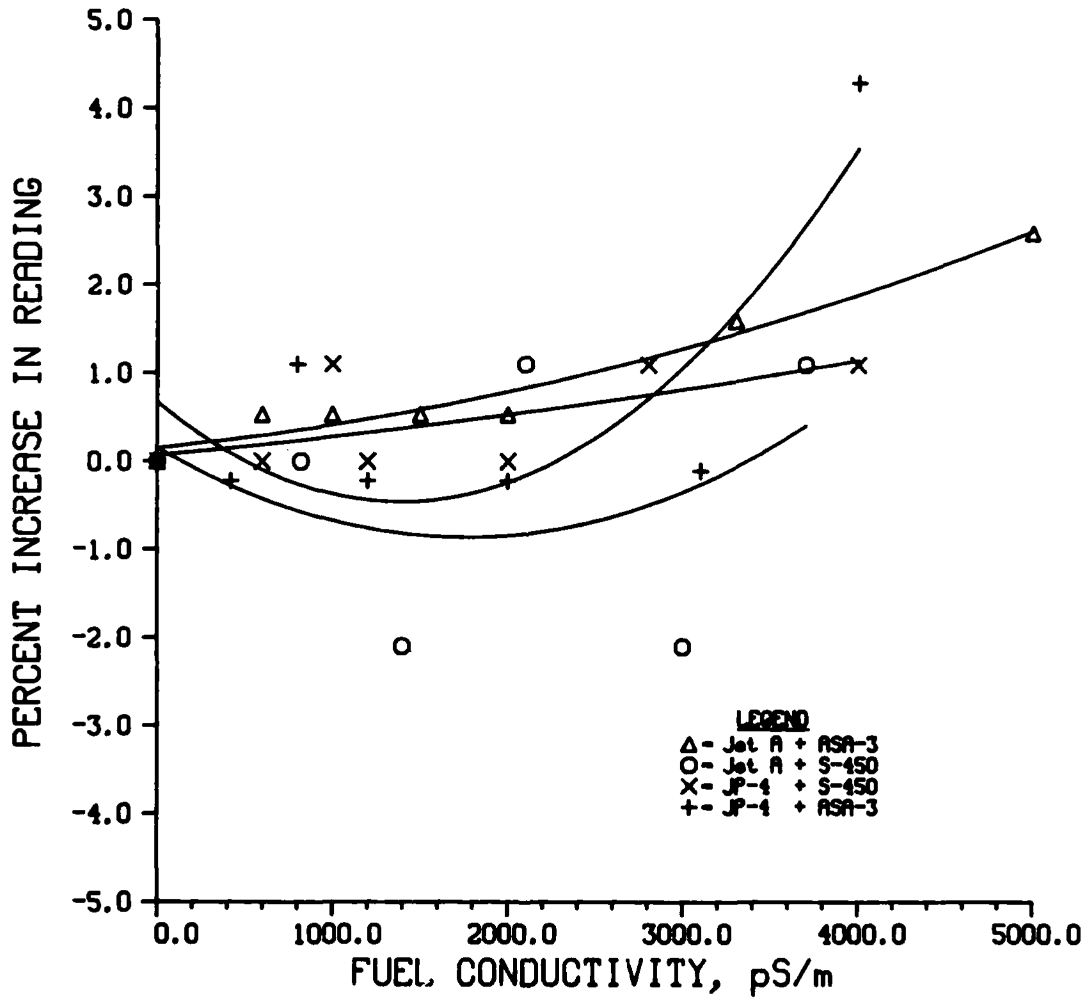

Figure 17. Percent Increase in Reading vs Fuel Conductivity A-7 System at Level 9³/₈

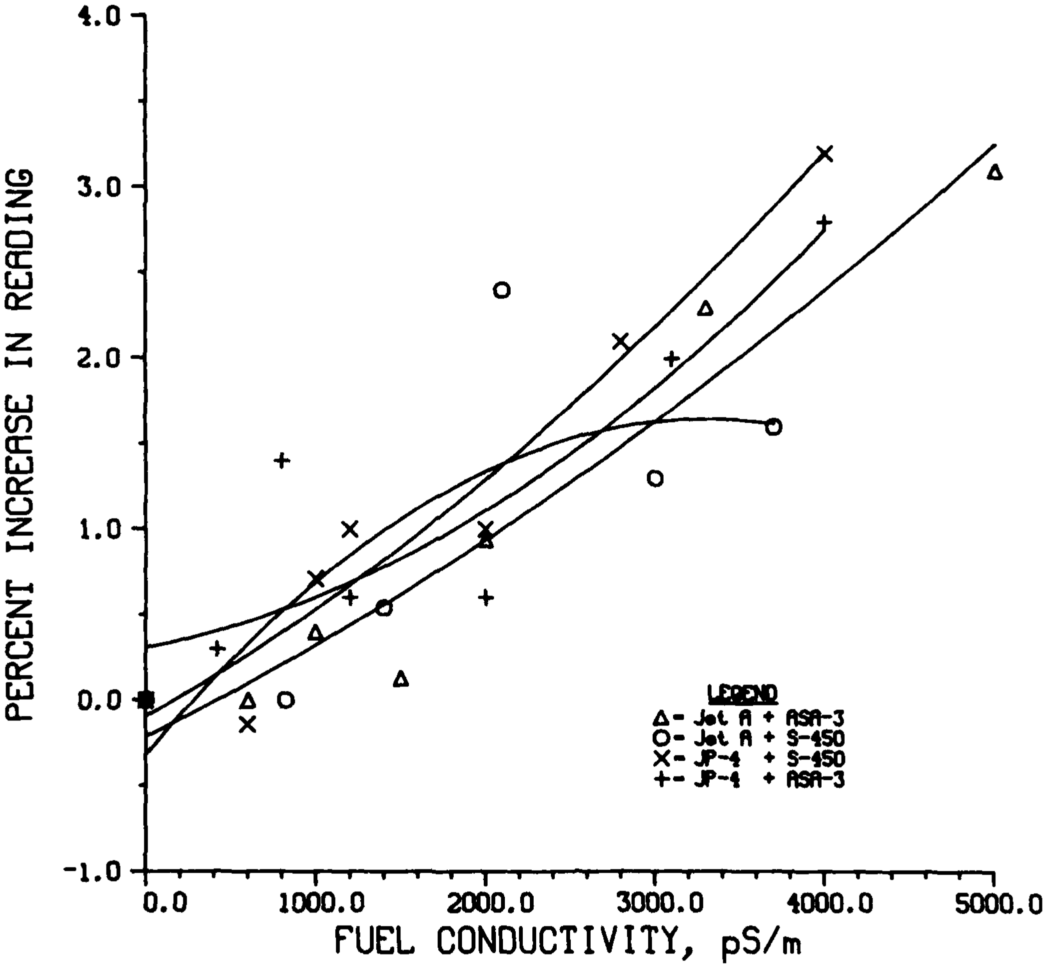

Figure 18. Percent Increase in Reading vs Fuel Conductivity A-7 System at Level 24¹/₄

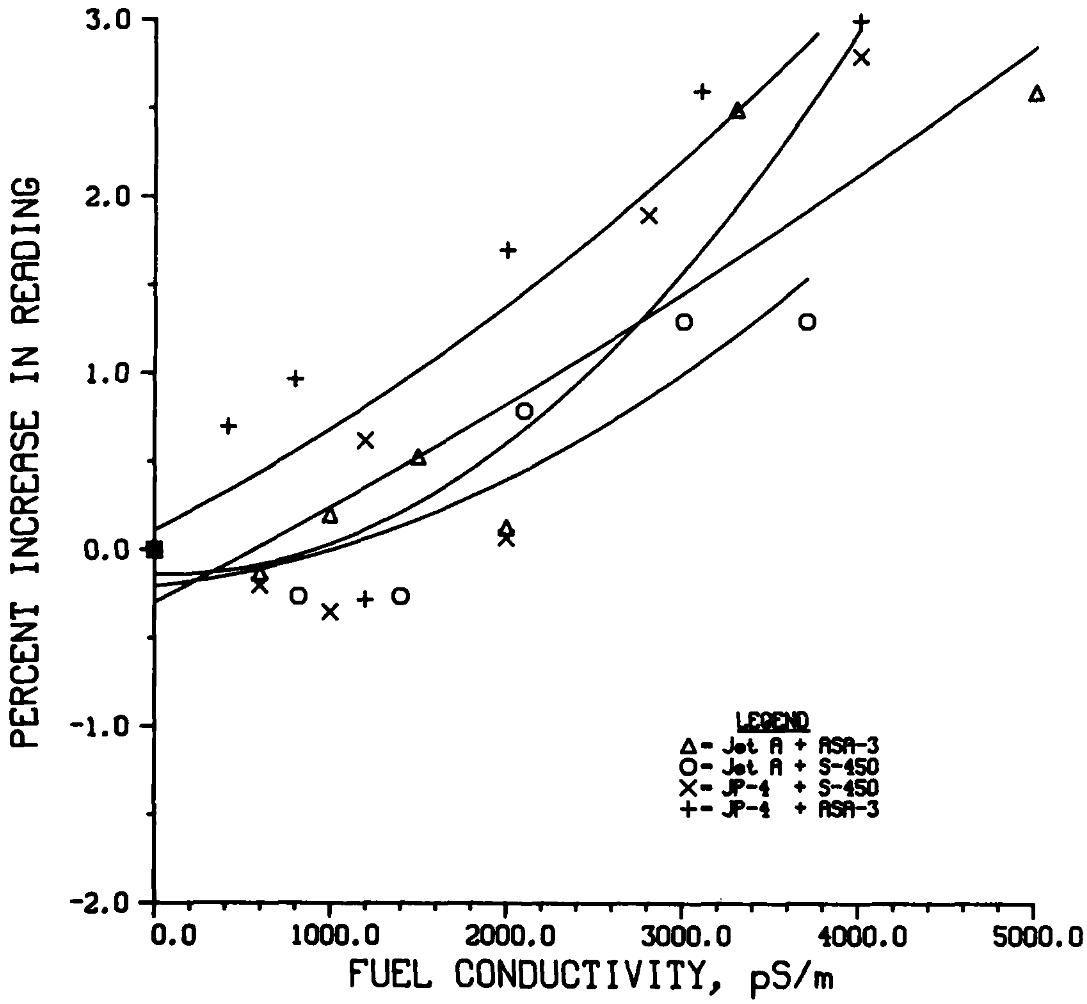

Figure 19. Increase in Reading vs Fuel Conductivity
A-7 System at Level 35 1/4

The increase in indicator reading at different fuel levels was fairly uniform, unlike the results obtained with the KC-135 system. This was probably due to differences in tank unit profiling and indicator circuitry.

One discrepancy is shown in the Appendix, Table A-10, where an empty reading of 340 lbs. was recorded. This was due to the fact that the voltmeter was inadvertently left connected while the level reading was being taken.

(2) Sensitivity

Figure 20 is a plot of sensitivity (as a change in ratiometer setting) vs fuel conductivity for the A-7 system. As with the KC-135 system, an increase in this parameter indicates a decrease in the system sensitivity.

The data indicate that at 4000 pS/m the system sensitivity has decreased by a factor of approximately 7. At 1000 pS/m, the sensitivity had decreased by approximately 16%. Using the equation given on page 5 relating the Δ ratio to lbs. sensitivity, the following changes in lbs. sensitivity are indicated:

Conductivity (pS/m)	Average Sensitivity	
	Lbs.	% of Full Scale
20	40.0	0.25%
500	43.0	0.28%
1000	46.7	0.31%
2000	66.7	0.44%
4000	380	2.51%

(3) Speed of Response

The speed of response for the A-7 system was measured in the same manner as described for the KC-135 system. The results obtained are shown in Figure 21. At 500 pS/m an average increase of approximately 1.8% in the response time was observed. At 1000 pS/m this had increased to approximately 5.1% and at 4000 pS/m as much as a 28% increase in response time occurred. This was a much greater increase than that observed with the KC-135 system, where the maximum increase was approximately 8%.

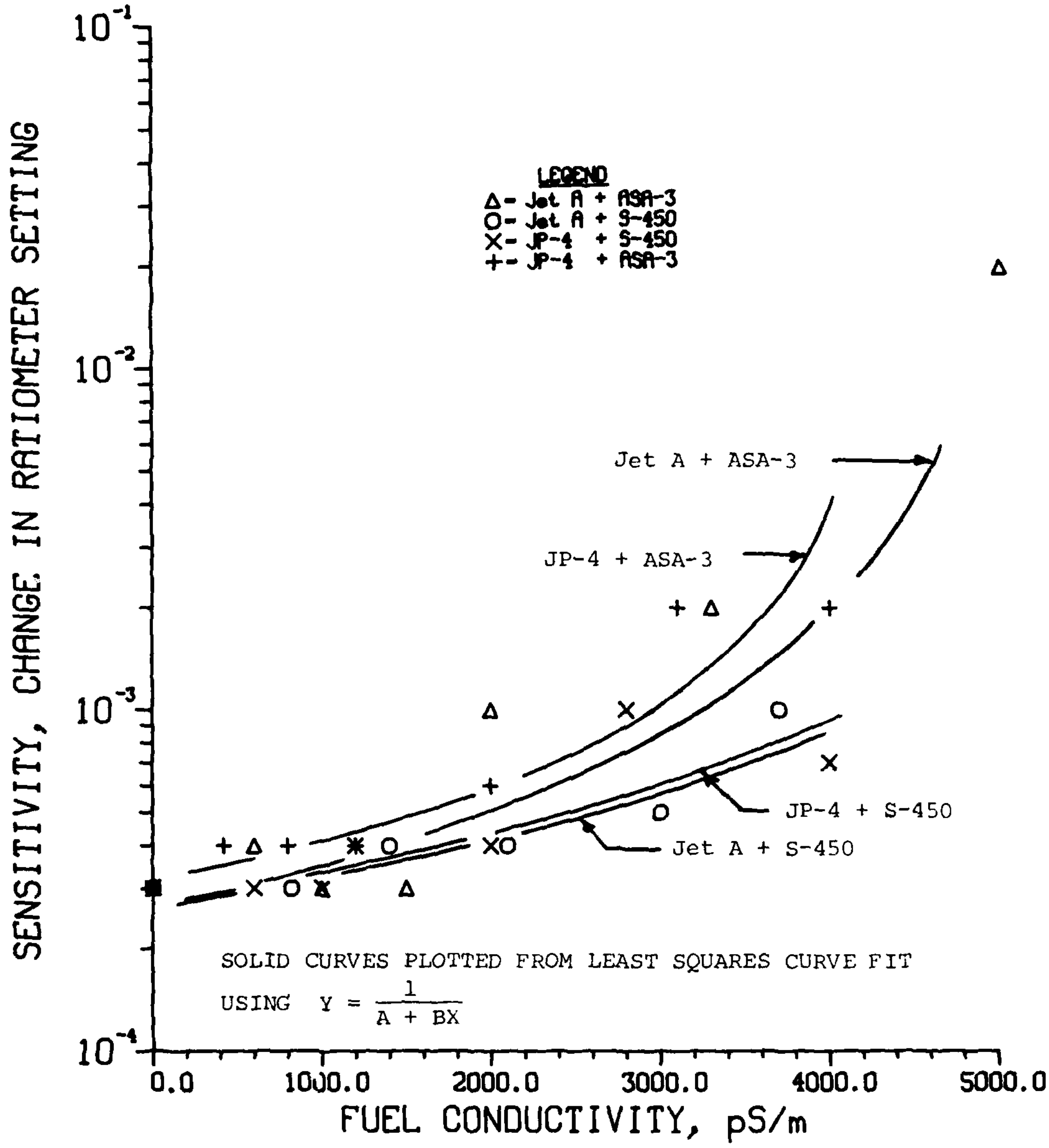

Figure 20. Sensitivity vs Fuel Conductivity
A-7 System

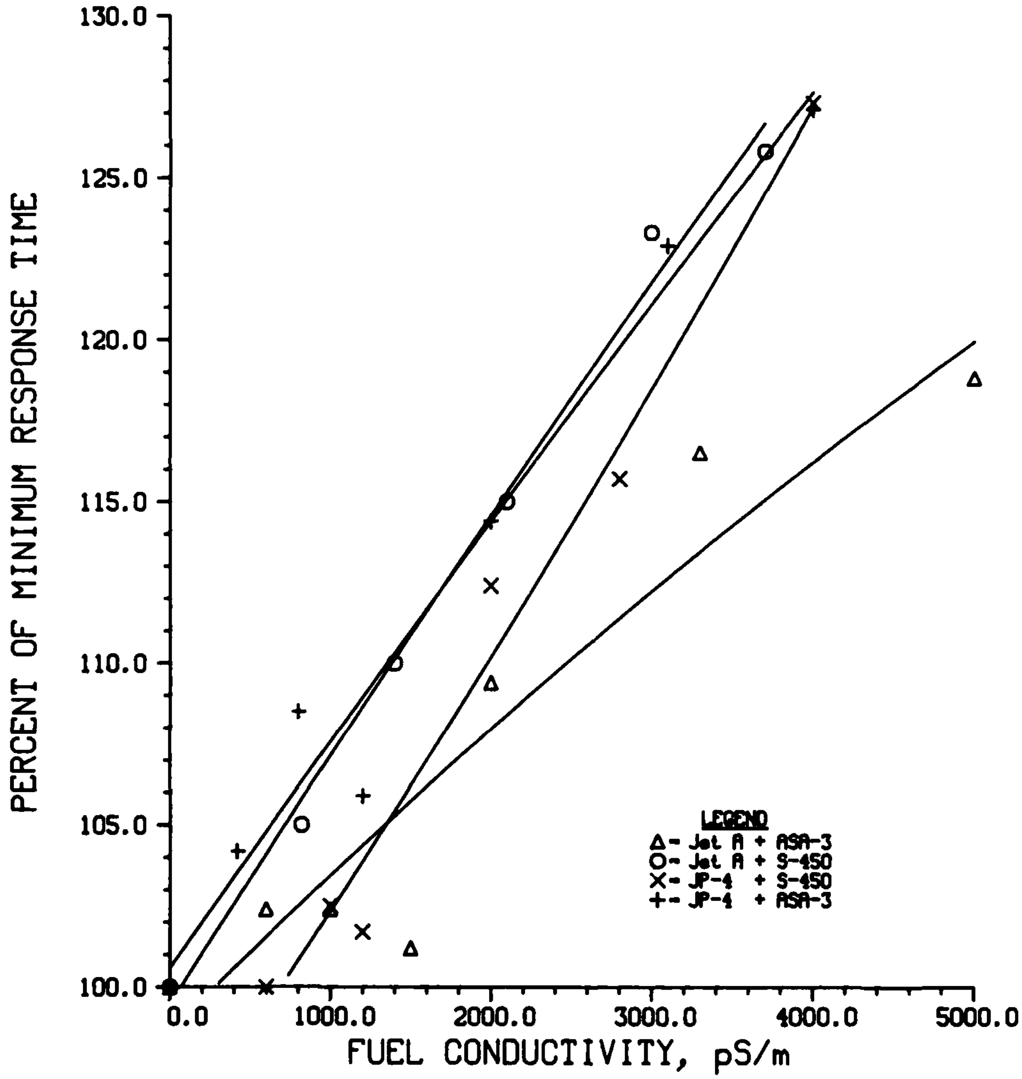

Figure 21. Percent of Minimum Response Time vs Fuel Conductivity
A-7 System

(4) High Z Null Voltage

In an attempt to eliminate some of the scatter observed in the oscilliscope readings of this parameter taken with the KC-135 system, a digital voltmeter was used to read the RMS null voltage for the A-7 system. The results are shown in Figure 22.

Ignoring the one outlier data point at <20 pS/m conductivity (see Figure 22), a steady increase in the High Z null voltage with increasing fuel conductivity was seen:

Conductivity pS/m	Average % Increase in High Z Null Voltage
500	62.6
1000	92
2000	179
3000	302
4000	463

4. F-16 SYSTEM

a. Test Set-Up

The test set-up for the F-16 system was similar to that used for the F-15, and a schematic for this is shown in Figure 23. Results obtained for this system were very similar to those obtained with the F-15 system. Photographs of the test equipment are shown in Figure 24.

b. Data Obtained

The data obtained on the F-16 system are tabulated in the Appendix, Tables A-13 through A-16. Since there were no significant changes observed with increasing fuel conductivity, no graphs of these data were prepared.

(1) Full Scale Reading

A maximum reading of 2120 lbs. to 2200 lbs. was obtained with the test set-up. The normal system maximum for the pointer is 4000 lbs. No changes in any of the scale readings were observed up to conductivity levels of 5000 pS/m.

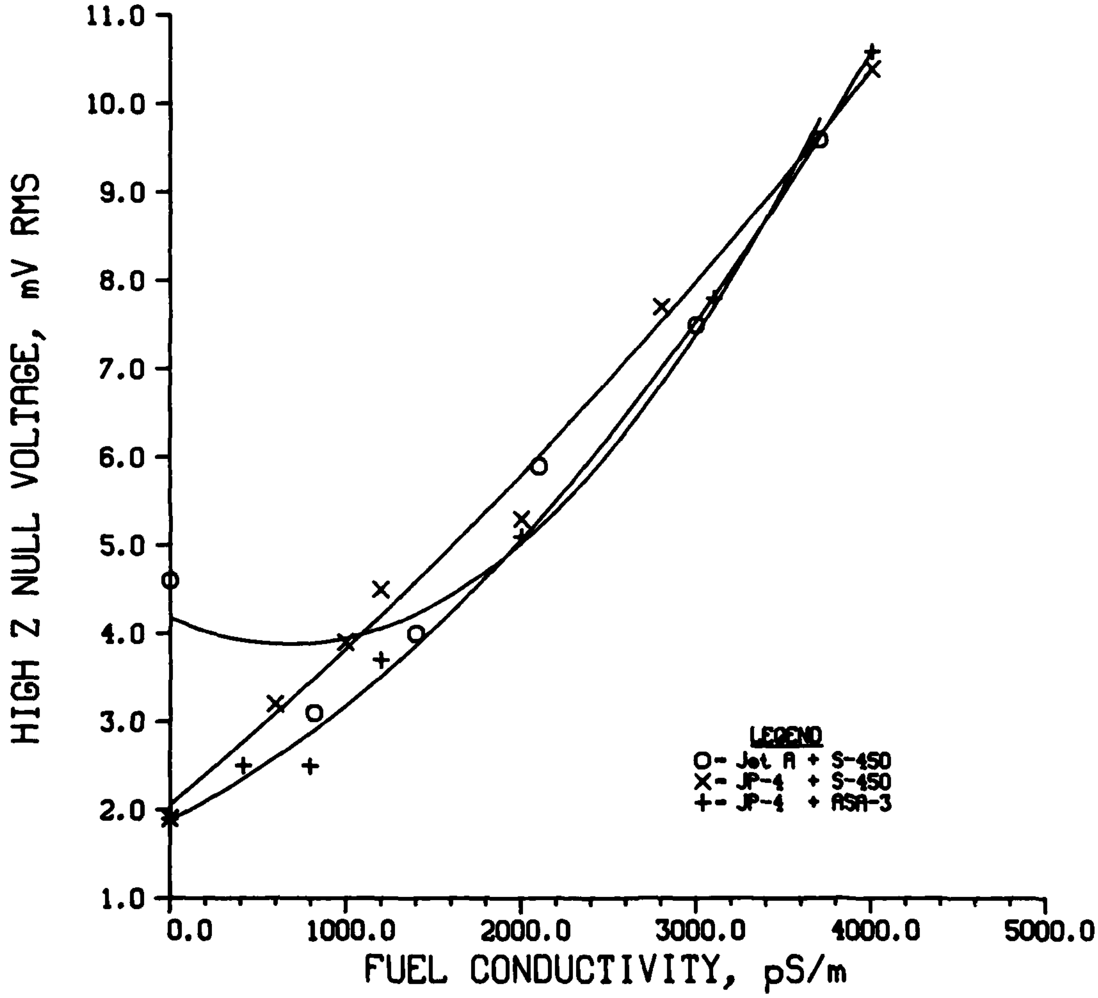

Figure 22. High Z Null Voltage vs Fuel Conductivity
A-7 System

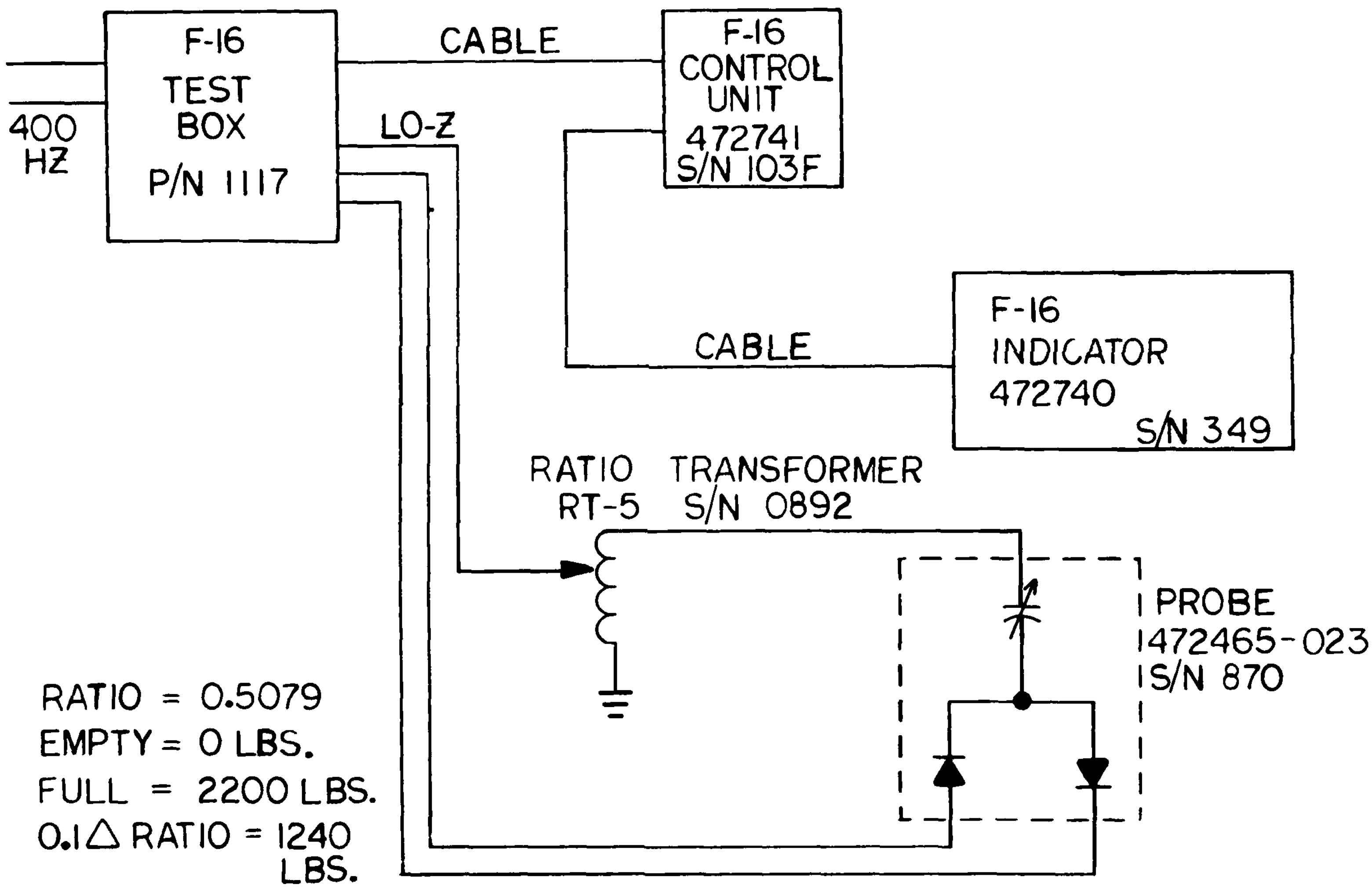

Figure 23. F-16 Test Set-Up

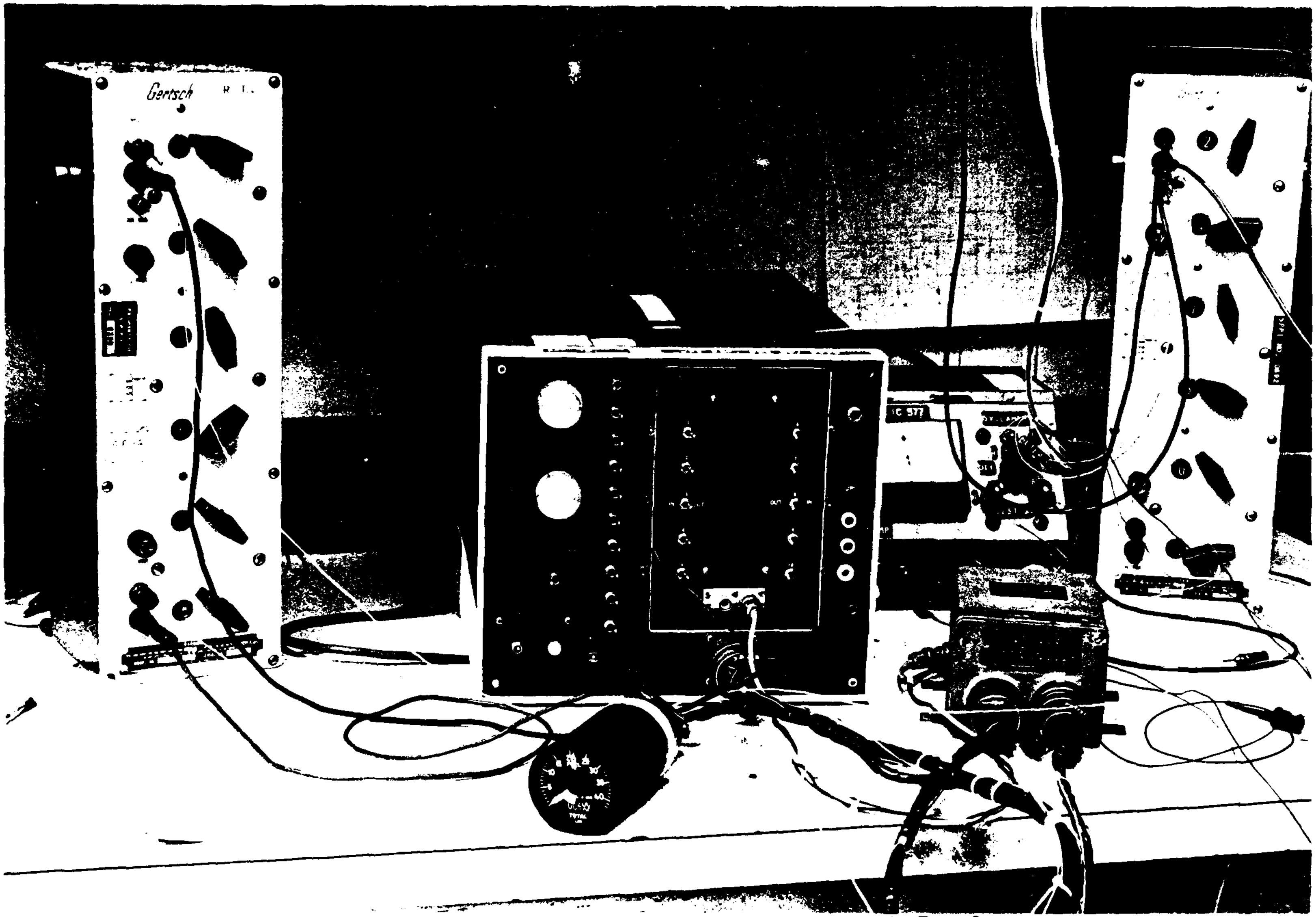

Figure 24. F-16 Indicator, Control Unit, Power Supply and Ratio Transformer

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(2) Sensitivity

All the data obtained indicate no change in system sensitivity for fuel conductivity levels up to 5000 pS/m.

(3) Speed of Response

The speed of response of the F-16 system was checked on the Jet A + Stadis 450, JP-4 + ASA-3, and the JP-4 + Stadis 450 runs. Examination of the data obtained in Tables A-14, A-15, and A-16 of the Appendix indicates no significant variation in this parameter with fuel conductivities up to 5000 pS/m.

SECTION V

THEORETICAL ANALYSIS

The high frequency D.C. Systems are virtually immune to these levels of fuel conductivity for two reasons.

(1) The 6 KHz frequency reduces the probe error due to conductivity by a factor of $(6000/400)^2 = 225$ as follows:

$$Y = \sigma - j\,2\,\pi\,f\,C$$

Where: Y = actual probe admittance (a complex number)
σ = fuel conductivity term
C = probe capacitance
j = designates term at 90^0 phase angle
f = excitation frequency

In this equation $2\,\pi\,f\,C$ is the true fuel quantity term. σ is the error term added due to fuel conductivity.

Where $\sigma << 2\,\pi\,f\,C$ and for a given probe capacitance (C) the probe error (Y_{error}), due to the added fuel conductivity term (σ), is approximately proportional to $(\sigma/f)^2$ as follows:

$$Y_{error} = \frac{\text{(magnitude of probe admittance vector) - (true fuel quantity term)}}{\text{(true fuel quantity term)}}$$

$$Y_{error} = \frac{\sqrt{\sigma^2 + 4\,\pi^2\,f^2\,C^2} - [2\,\pi\,f\,C]}{2\,\pi\,f\,C} \approx (A)(\sigma/f)^2$$

Where: A = a constant related to a given probe

Thus, if f is increased by a factor of 15, the probe error is decreased by a factor of 225.

(2) The D.C. system is totally insensitive to phase shift caused by fuel conductivity. High Z null voltages and speed of response times are totally independent of the probe phase angle because the D.C. system measures the absolute value of the probe signal.

In the 400 Hz AC systems the probe capacitance is the key factor in producing the necessary 90 degree phase shift for servo motor drive. Any degradation in the phase angle of the probe capacitance will affect servo sensitivity. The fuel conductivity term (σ) directly affects the phase angle.

SECTION VI

CONCLUSIONS

Based on the test data obtained, the following conclusions concerning the impact of anti-static additives on aircraft capacitance type fuel gauging systems were drawn:

1. The use of Stadis 450 or ASA-3 additives to increase jet fuel electrical conductivity up to 5000 pS/m has no effect on the high frequency DC capacitance gauging systems used in the F-15 and F-16 aircraft.

2. The use of Stadis 450 or ASA-3 additives to increase jet fuel electrical conductivity up to 500 pS/m will have a minimal affect on the older 400 Hz AC capacitance gauging systems.

3. No significant differences in system performance between the two additives nor the two fuels were observed.

APPENDIX

TABLES OF TEST DATA

TABLE A-1 DATA FOR THE KC-135 SYSTEM USING JET A WITH STADIS 450

DATE	8/13/79	8/15/79	8/16/79	8/17/79	8/20/79	8/21/79	8/22/79	8/23/79	8/24/79
CONDUCTIVITY, pS/m	20	60	290	470	800	1100	1800	2800	3700
	GAGE READING, lbs								
FUEL LEVEL									
47-3/8 INCHES	32,275	32,250	32,390	32,500	32,790	32,825	33,150	33,100	33,350
35-1/4 INCHES	21,690	21,640	21,890	21,890	22,175	22,210	22,475	22,525	22,700
24-1/4 INCHES	12,500	12,500	12,590	12,620	12,710	12,800	13,050	13,250	13,225
9-3/8 INCHES	2,780	2,875	2,910	2,950	2,900	2,975	3,050	3,225	3,250
EMPTY	0	0	0	0	0	0	50	100	120
RATIO:	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595
SENSITIVITY	0.0007	0.0007	0.0009	0.0009	0.001	0.001	0.0017	0.003	0.0045
RESPONSE TIME, sec	27	27	27	27	27	27	27	28	29
HIGH Z NULL, mV		80	140	100	140	80	100	250	140

TABLE A-2 DATA FOR THE KC-135 SYSTEM USING JET A WITH ASA-3

DATE	8/28/79	8/29/79	8/29/79	8/30/79	8/30/79	9/4/79	9/4/79
CONDUCTIVITY, pS/m	20	380	900	1600	2200	3300	4300
	GAGE READING, lbs						
FUEL LEVEL							
47-3/8 INCHES	32,150	32,500	32,600	33,050	32,900	33,400	32,975
35-1/4 INCHES	21,580	21,880	21,920	22,390	22,375	22,950	22,600
24-1/4 INCHES	12,410	12,675	12,640	12,950	12,990	13,620	13,440
9-3/8 INCHES	2,860	2,890	2,950	3,100	3,025	3,320	3,325
EMPTY	0	0	0	100	75	20	90
RATIO	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595
SENSITIVITY	0.0009	0.001	0.001	0.0014	0.002	0.003	0.0045
RESPONSE TIME, sec	30	30	29	29	30	31	31
HIGH Z NULL, mV	140	120	160	115	120	180	180

TABLE A-3 DATA FOR THE KC-135 SYSTEM USING JP-4 WITH ASA-3

DATE	9/5/79	9/6/79	9/6/79	9/7/79	9/7/79	9/10/79
CONDUCTIVITY, pS/m	20	1000	1400	1900	3000	5000
FUEL LEVEL	GAGE READING, lbs					
47-3/8 INCHES	30,750	31,410	31,500	31,625	31,675	32,050
35-1/4 INCHES	20,700	21,150	21,380	21,400	21,550	22,025
24-1/4 INCHES	11,910	12,200	12,750	12,400	12,680	13,100
9-3/8 INCHES	2,775	2,725	3,000	2,790	3,000	3,300
EMPTY	0	100	0	75	0	100
RATIO	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595
SENSITIVITY	0.001	0.0018	0.003	0.003	0.004	0.009
RESPONSE TIME, sec	28	28	28	28	29	30
HIGH Z NULL, mV	120	160	190	120	200	250

TABLE A-4 DATA FOR THE KC-135 SYSTEM USING JP-4 WITH STADIS 450

DATE	9/11/79	9/12/79	9/12/79	9/13/79	9/13/79	9/14/79
CONDUCTIVITY, pS/m	20	700	1200	2000	3200	4000
FUEL LEVEL	GAGE READING, lbs					
47-3/8 INCHES	30,825	30,825	31,200	31,600	31,650	31,575
35-1/4 INCHES	20,675	20,675	21,125	21,325	21,300	21,380
24-1/4 INCHES	11,900	11,900	12,180	12,375	12,502	12,550
9-3/8 INCHES	2,700	2,700	2,790	2,850	2,925	3,000
EMPTY	0	0	0	0	0	0
RATIO	0.8595	0.8595	0.8595	0.8595	0.8595	0.8595
SENSITIVITY	0.0014	0.0025	0.0026	0.0029	0.004	0.0035
RESPONSE TIME, sec	27	27	28	28	28	29
HIGH Z NULL, mV	180	200	225	110	130	150

TABLE A-5 DATA FOR THE F-15 SYSTEM USING JP-4 WITH STADIS 450

DATE	9/11/79	9/12/79	9/12/79	9/13/79	9/13/79	9/14/79
CONDUCTIVITY, pS/m	20	700	1200	2000	3200	4000
FUEL LEVEL	GAGE READING, lbs					
47-3/8 INCHES	2810	2810	2790	2800	2800	2800
35-1/4 INCHES	2090	2080	2090	2090	2090	2090
24-1/4 INCHES	1340	1340	1340	1340	1340	1340
9-3/8 INCHES	375	375	375	375	375	375
EMPTY	0	0	0	0	0	0
RATIO	0.6530	0.6530	0.6530	0.6530	0.6530	0.6530
SENSITIVITY	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004

TABLE A-6 DATA FOR THE F-15 SYSTEM USING JP-4 WITH ASA-3

DATE	9/5/79	9/6/79	9/6/79	9/7/79	9/7/79	9/10/79
CONDUCTIVITY, pS/m	20	1000	1400	1900	3000	5000
FUEL LEVEL	GAGE READING, lbs					
47-3/8 INCHES	2790	2790	2790	2800	2825	2825
35-1/4 INCHES	2080	2080	2080	2080	2100	2100
24-1/4 INCHES	1360	1360	1360	1360	1350	1360
9-3/8 INCHES	375	375	375	375	375	380
EMPTY	0	0	0	0	0	0
RATIO	0.6530	0.6530	0.6530	0.6530	0.6530	0.6530
SENSITIVITY	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004

TABLE A-7 DATA FOR THE F-15 SYSTEM USING JET A WITH STADIS 450

DATE	8/13/79	8/15/79	8/16/79	8/17/79	8/20/79	8/21/79	8/22/79	8/23/79	8/24/79
CONDUCTIVITY, pS/m	20	60	290	470	800	1100	1800	2800	3700
FUEL LEVEL	GAGE READING, lbs								
47-3/8 INCHES	2925	2950	2950	2950	2950	2950	2950	2950	2950
35-1/4 INCHES	2190	2200	2200	2200	2200	2200	2200	2190	2190
24-1/4 INCHES	1425	1410	1410	1410	1410	1410	1410	1410	1410
9-3/8 INCHES	390	390	390	390	390	390	390	390	390
EMPTY	0	0	0	0	0	0	0	0	0
RATIO	0.6530	0.6530	0.6530	0.6530	0.6530	0.6530	0.6530	0.6530	0.6530
SENSITIVITY	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003	0.0004	0.0004	0.0004

TABLE A-8 DATA FOR THE F-15 SYSTEM USING JET A WITH ASA-3

DATE	8/28/79	8/29/79	8/29/79	8/30/79	8/31/79	9/4/79	9/4/79
CONDUCTIVITY, pS/m	20	380	900	1600	2200	3300	4300
FUEL LEVEL	GAGE READING, lbs						
47-3/8 INCHES	2925	2925	2925	2925	2925	2925	2925
35-1/4 INCHES	2190	2190	2190	2190	2190	2190	2190
24-1/4 INCHES	1425	1425	1425	1425	1425	1425	1425
9-3/8 INCHES	390	390	390	390	390	390	390
EMPTY	0	0	0	0	0	0	0
RATIO	0.6530	0.6530	0.6530	0.6530	*0.6487	0.6487	0.6487
SENSITIVITY	0.0003	0.0004	0.0004	0.0005	0.0004	0.0004	0.0004

* Original probe was replaced with another due to shipping requirement, and a change in ratiometer setting was necessary to zero the probe.

TABLE A-9 DATA FOR THE A-7 SYSTEM USING JET A WITH ASA-3

DATE	10/5/79	10/8/79	10/8/79	10/9/79	10/9/79	10/10/79	10/10/79
CONDUCTIVITY	20	600	1000	1500	2000	3300	5000
FUEL LEVEL	GAGE READING, lbs						
35-1/4 INCHES	15,120	15,100	15,150	15,200	15,140	15,500	15,520
24-1/4 INCHES	7450	7450	7480	7460	7520	7620	7680
9-3/8 INCHES	1890	1900	1900	1900	1900	1920	1940
BOTTOM	0	0	0	0	0	40	40
RATIO	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480
SENSITIVITY	0.0003	0.0004	0.0003	0.0003	0.001	0.002	0.02
RESPONSE TIME, sec	17	17.4	17.4	17.2	18.6	19.8	20.2
HIGH Z NULL	150 mV AC p-p	150 mV AC p-p	130 mV AC p-p	50 mV AC p-p	80 mV AC p-p	100 mV AC p-p	40 mV AC p-p

TABLE A-10 DATA FOR THE A-7 SYSTEM USING JET A WITH STADIS 450

DATE	10/16/79	10/17/79	10/17/79	10/18/79	10/18/79	10/19/79
CONDUCTIVITY	20	820	1400	2100	3000	3700
FUEL LEVEL	GAGE READING, lbs					
35-1/4 INCHES	15,120	15,080	15,080	15,240	15,320	15,320
24-1/4 INCHES	7440	7440	7480	7620	7540	7560
9-3/8 INCHES	1900	1900	1860	1920	1860	1920
BOTTOM	0	-40	0	0	340*	40
RATIO	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480
SENSITIVITY	0.0003	0.0003	0.0004	0.0004	0.0005	0.001
RESPONSE TIME, sec	12	12.6	13.2	13.8	14.8	15.1
HIGH Z NULL	4.6 mV AC rms	3.1 mV AC rms	4.0 mV AC rms	5.9 mV AC rms	7.5 mV AC rms	9.6 mV AC rms

TABLE A-11 DATA FOR THE A-7 SYSTEM USING JP-4 WITH STADIS 450

DATE	10/19/79	10/22/79	10/22/79	10/23/79	10/23/79	10/24/79	10/24/79
CONDUCTIVITY	20	600	1000	1200	2000	2800	4000
FUEL LEVEL	GAGE READING, lbs						
35-1/4 INCHES	14,490	14,460	14,440	14,580	14,500	14,760	14,900
24-1/4 INCHES	7090	7080	7140	7160	7160	7240	7320
9-3/8 INCHES	1780	1780	1800	1780	1780	1800	1800
BOTTOM	0	-20	0	-40	-40	-60	-20
RATIO	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480
SENSITIVITY	0.0003	0.0003	0.0003	0.0004	0.0004	0.001	0.0007
RESPONSE TIME, sec	-	12.1	12.4	12.3	13.6	14	15.4
HIGH Z NULL	1.9 mV AC rms	3.2 mV AC rms	3.9 mV AC rms	4.5 mV AC rms	5.3 mV AC rms	7.7 mV AC rms	10.4 mV AC rms

TABLE A-12 DATA FOR THE A-7 SYSTEM USING JP-4 WITH ASA-3

DATE	10/25/79	10/26/79	10/29/79	10/29/79	10/30/79	10/30/79	10/31/79
CONDUCTIVITY	20	420	800	1200	2000	3100	4000
FUEL LEVEL	GAGE READING, lbs						
35-1/4 INCHES	14,500	14,600	14,640	14,460	14,740	14,880	14,940
24-1/4 INCHES	7160	7180	7260	7200	7200	7300	7360
9-3/8 INCHES	1840	1800	1860	1800	1800	1820	1920
BOTTOM	0	-40	-60	-40	-40	-40	20
RATIO	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480	0.2480
SENSITIVITY	0.0003	0.0004	0.0004	0.0004	0.0006	0.002	0.002
RESPONSE TIME, sec	11.8	12.3	12.8	12.5	13.5	14.5	15.0
HIGH Z NULL	1.9 mV AC rms	2.5 mV AC rms	2.5 mV AC rms	3.7 mV AC rms	5.1 mV AC rms	7.8 mV AC rms	10.6 mV AC rms

TABLE A-13 DATA FOR THE F-16 SYSTEM USING JET A WITH ASA-3

DATE	10/5/79	10/8/79	10/8/79	10/9/79	10/9/79	10/10/79	10/10/79
CONDUCTIVITY	20	600	1000	1500	2000	3300	5000
FUEL LEVEL	GAGE READING, lbs						
FLOODED	2210	2200	2200	2200	2200	2200	2200
35-1/4 INCHES	2040	2050	2040	2040	2040	2040	2040
24-1/4 INCHES	1490	1500	1500	1500	1500	1500	1500
9-3/8 INCHES	20	20	20	20	20	20	20
BOTTOM	0	0	0	0	0	0	0
RATIO	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079
SENSITIVITY	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
RESPONSE TIME	-	-	-	-	-	-	-
HIGH Z NULL	-	-	-	-	-	-	-

TABLE A-14 DATA FOR THE F-16 SYSTEM USING JET A WITH STADIS 450

DATE	10/16/79	10/17/79	10/17/79	10/18/79	10/18/79	10/19/79
CONDUCTIVITY	20	820	1400	2100	3000	3700
FUEL LEVEL	GAGE READING, lbs					
FLOODED	2200	2200	2200	2200	2200	2200
35-1/4 INCHES	2040	2040	2040	2040	2040	2040
24-1/4 INCHES	1500	1500	1500	1500	1500	1500
9-3/8 INCHES	20	20	20	20	20	20
BOTTOM	0	0	0	0	0	0
RATIO	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079
SENSITIVITY	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
RESPONSE TIME, sec	-	-	6.2	6.5	6.5	6.6
HIGH Z NULL	-	-	-	-	-	-

TABLE A-15 DATA FOR THE F-16 SYSTEM USING JP-4 WITH STADIS 45C

DATE	10/19/79	10/22/79	10/22/79	10/23/79	10/23/79	10/24/79	10/24/79
CONDUCTIVITY	20	600	1000	1200	2000	2800	4000
FUEL LEVEL	GAGE READING, lbs						
FLOODED	2120	2120	2120	2120	2120	2120	2120
35-1/4 INCHES	1960	1960	1960	1960	1960	1960	1960
24 1/4 INCHES	1420	1420	1420	1420	1420	1420	1420
9-3/8 INCHES	20	20	20	20	20	20	20
BOTTOM	-20	-20	-20	-20	-20	-20	-20
RATIO	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079
SENSITIVITY	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
RESPONSE TIME, sec	-	6.1	6.4	6.0	6.3	5.8	6.4
HIGH Z NULL	-	-	-	-	-	-	-

TABLE A-16 DATA FOR THE F-16 SYSTEM USING JP-4 WITH ASA-3

DATE	10/26/79	10/26/79	10/29/79	10/29/79	10/30/79	10/31/79	10/31/79
CONDUCTIVITY	20	420	800	1200	2000	3100	4000
FUEL LEVEL	GAGE READING, lbs						
FLOODED	2120	2120	2120	2120	2120	2120	2120
35-1/4 INCHES	1960	1960	1960	1960	1960	1960	1960
24-1/4 INCHES	1420	1420	1420	1420	1420	1420	1420
9-3/8 INCHES	20	20	20	20	20	20	20
BOTTOM	0	-20	-20	-20	-20	-20	-20
RATIO	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079
SENSITIVITY	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
RESPONSE TIME, sec	6.2	6.3	6.1	5.8	6.0	6.5	5.9
HIGH Z NULL	-	-	-	-	-	-	-

*U.S.Government Printing Office: 1980 — 757-002/227